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Materials Research & Standards

Bulletin of AMERICAN SOCIETY FOR TESTING MATERIALS

$$ST_0/RTa_T = \int_{-\infty}^{\infty} M(\tau)\tau(1-e^{-\tau/Rta_T})\,d\ln\tau$$

.....OR HOW TO PREDICT VISCOELASTIC BEHAVIOR FROM SIMPLE STRESS-STRAIN DATA

The above formula, recently developed with an assist from Instron, enables rheologists to predict, with accuracy, the complex linear viscoelastic properties of certain polymers from simple stress-strain data. For example, it is possible to calculate stress-relaxation modulus from a simple tension test.

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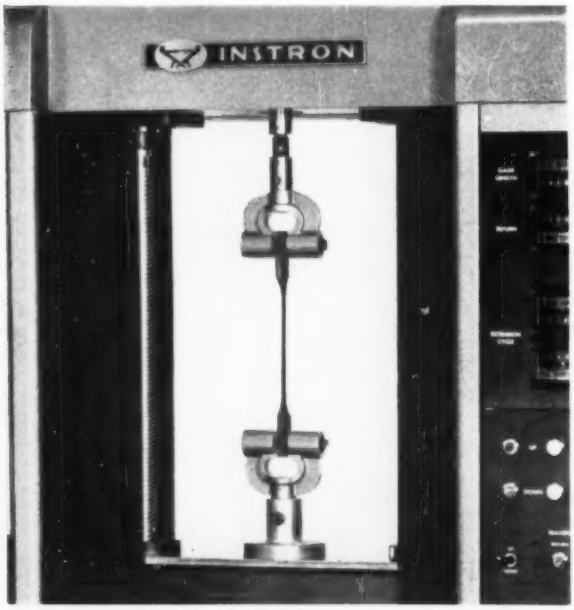
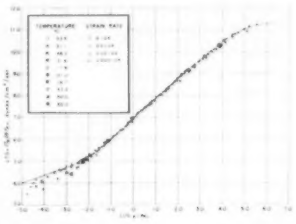
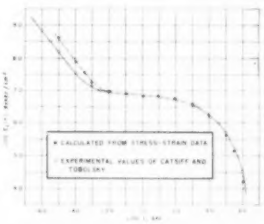


The Instron's servo-controlled testing speed was extremely useful in the test. The constant crosshead speed imposed constant strain rate in the sample for elongations up to 150%. Unique extension-recording system of the Instron made it possible to measure strain accurately without extensometers.



Stress-strain data reduced to unit strain rate at 298°K.



Stress-relaxation modulus derived from stress-strain data compared with experimental data of Catsiff and Tobolsky.

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$$ST_0/RTa_T = \int_{-\infty}^{\infty} M(\tau)\tau(1-e^{-\tau/Rta_T})\,d\ln\tau$$

How the formula was used: Samples of synthetic, non-crossed linked rubber were tested at 10 temperatures between −54° and 85°C. and at constant strain rates between 0.014 and 0.104 x 10^{-1} sec^{-1} on the Instron Universal Tester. Stress-strain data were reduced mathematically to unit strain rate to yield a single curve for each temperature. Curves were then superposed to determine temperature dependence of viscosity, then all data up to 100% elongation were reduced to a single stress-strain curve accurately predicting viscoelastic behavior over nine decades of reduced time. It was shown that stress-relaxation modulus could be calculated satisfactorily from the reduced stress-strain curve.

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TECHNICAL PAPERS

SYMPOSIUM ON QUALITY OF OBSERVATIONS

* * *

ARTICLES

DEPARTMENTS

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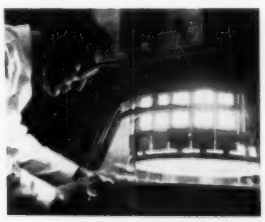

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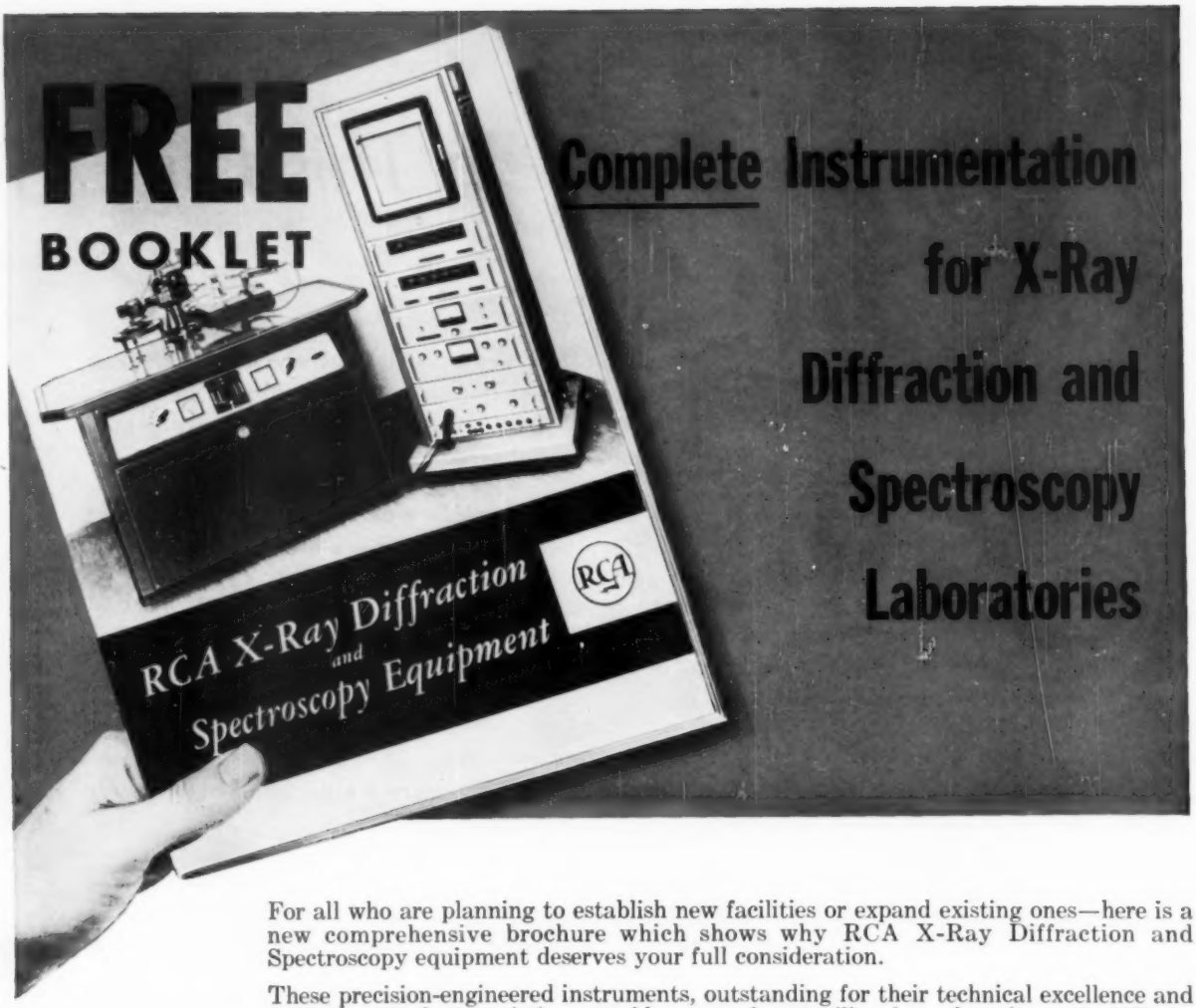

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Materials
Research & Standards

Volume 1, Number 4, April, 1961

COMMENT

How Big Is Your Appetite?

WE HEARD the story not too long ago (we have forgotten just where) about the little girl who was asked for her opinion of a book about penguins that someone had given her. Quite soberly, she replied, "This is a very good book, but it tells me more about penguins than I want to know."

Publishers and authors of every variety must struggle with this problem—how much goes in and how much is left out? In the world of technical publications, in particular, this has ceased to be a question of aesthetics, or even of mere economics—it is a question of sheer survival. Unless we can find a way to cope with the growing flood of material to be published, we are in danger of drowning in it.

There are undoubtedly those who are haunted by feelings of incompleteness whenever a technical paper does not include every last number available to the author. On the other hand, most readers would probably agree that data are much easier to assimilate in graphical form. What strikes us as a very sensible attack on this problem, within ASTM, has come in the form of a recommendation at the meeting of the Administrative Committee on Papers and Publications, February 10. That recommendation is:

"In order to reduce publishing costs without compromising the author's intentions, it should be a general policy, for technical papers containing extensive tabulations, and except where statistical studies are being made, that the data be given primarily in graphical or summary-table form, and that substantiating tables be supplied to reviewers and discussers and kept in the Society's files for no more than five years and discarded if inquiries during that period have been negligible. It is presumed that the summary tables will indicate the number of tests involved for an average and the philosophy used in arriving at the summation."

Except for those few who suffer attacks of vertigo at the sight of long, even columns of numbers in small type, the institution of such a measure would do little toward easing the burden on the reader. As things now stand, the data are there in the tables for him to inspect or ignore, as he pleases. Elimination of very detailed tabulations would, however, make room for more papers per publication page. It would also decrease publication costs per page, since tables are much more costly to set in type than straight text material or illustrations. The question is, do we gain more than we lose?

This proposal is slated for discussion at the next meeting of the papers committee, in the fall. Letters from *MR&S* readers on this question will be most welcome and will be passed on to the committee for its guidance. How much do *you* want to know about penguins?

A.Q.M.

Quality of Observations*

NOTE.—Reprints of "Quality of Observations," including the following four papers plus discussion, are available from ASTM Headquarters. Prices on request.

YOUR test program is now complete and your file bulges with numbers. Two questions arise: How big are the numbers? How good are they? The following four papers address themselves to the second question. Here you will find definitions of those much-debated terms, "precision" and "accuracy," together with methods for determining them. Here you will also find suggestions on how to plan your experiments so as to improve the quality of your observations.

On the Meaning of Precision and Accuracy

By R. B. MURPHY

FOR SOME YEARS, the terms precision and accuracy have been used in connection with problems of measurement. About ten years ago ASTM Committee E-11 on Quality Control of Materials set itself the task of setting down some definitions for these two ideas. Their work on this subject is not completely finished even now. The words "accuracy" and "precision" have appeared in many places in ASTM standards and practices over the years. Other committees besides E-11 have attempted to set down standard definitions.

Debates and arguments about these terms seem to go on and on, so that the job of setting down definitions is a tough one. It is always a problem in defining ideas to balance rigor and exactness against practicality and simplicity; and in the present case matters have been made worse by a rather prolonged disagreement over which of two particular meanings the word "accuracy" should come to have.

The Measurement Process

Before we discuss the development of the E-11 definitions, I should like to adopt some terms for purposes of discussion. First and foremost, I should like to draw a distinction between a measurement or test method and a measurement process. A test method consists of a prescription or written procedure by which one can go about the business of making measurements on the properties of some physical material. This prescription may be very specific indeed, but essentially it is a much more inanimate object than a measurement process. A measurement process includes: (*a*) measurement method, (*b*) system of causes, (*c*) repetition, and (*d*) capability of control. A measurement process we could call a realization of a method in terms of particular men, particular equipment, and particular material to be tested. Of course, there is the question of whether a process is loyal to the method that it attempts to follow, or whether two different processes should be considered realizations of the same method.

It is handy here to import some of the language of statistical quality control to further characterize a measurement process. A measurement process may be regarded as a product of a system of causes, some of which may or may not have been specified in the test method. The important thing at this point is to recognize the broad scope of meaning embraced by the notion of a system of causes. A system of causes encompasses: (*a*) the material, (*b*) operator, (*c*) instrument, (*d*) laboratory, and (*e*) day.

Following through with this line of thought borrowed from quality control, we shall add a requirement that an

* The following four papers and discussion were presented at the Thirty-fifth Session of the Sixty-third Annual Meeting of the Society, held in Atlantic City, N. J., July 1, 1960. The symposium was jointly sponsored by the Administrative Committee on Research and Committee E-11 on Quality Control of Materials. A. T. McPherson, associate director, National Bureau of Standards, was symposium chairman.

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

R. B. MURPHY is a native of Massachusetts who has spent most of his life in the New York metropolitan area. He holds graduate and undergraduate degrees in mathematics from Princeton University with time out for service in the U. S. Marine Corps in World War II. After teaching mathematics and statistics at Carnegie Institute of Technology, he took up his present work at Bell Telephone Laboratories, Inc., New York, N.Y. on statistical problems arising in quality assurance.

effort to follow a test method ought not to be known as a measurement process unless it is capable of statistical control. Capability of control means that either the measurements are the product of an identifiable statistical universe or an orderly array of such universes or, if not, the physical causes preventing such identification may themselves be identified and, if desired, isolated and suppressed. Incapability of control implies that the results of measurement are not to be trusted as indications of the physical property at hand—in short, we are not in any verifiable sense measuring anything. Of course, it is profoundly difficult to say how capability of control shall be ascertained.

There is, however, a relatively simple procedure or body of related procedures for substantiating—or even defining—a state of statistical control. If, in fact, we have statistical control—and not merely the capability of it—and if for some reason such control, however we gage it, appears to be lost, we would be ready, willing, and able to take some special action beyond that normally entailed in the test method alone. Such action would have the aim, of course, of restoring our confidence in the capability of the measurement process to be statistically controlled and, indeed, to restore such control, if possible.

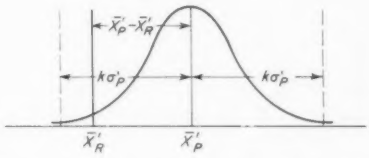
Why, one may ask, is there any need to impose the requirement of capability of statistical control? It is very simple. Without this limitation on the notion of measurement process, one is unable to go on to give meaning to those statistical measures which are basic to any discussion of precision and accuracy.

In any particular case, failure to have statistical control casts doubt on the sufficiency of our knowledge of the system of causes. It is then a question of determining which causes responsible for lack of statistical control should be acknowledged and included in our concept of the measurement process at hand and which should be eliminated so far as possible in their effect on the measurement process. Such elimination may entail a new prescription for the test method itself.

Reference Level or Target Value

One element of the system of causes which may be changed deliberately, although perhaps with unpredictable consequences, is what we may call the reference level of the quality of the material tested. A change of material would ordinarily imply a change in the reference level. This single cause in the system of causes has a unique position of importance in any measurement process. Some people prefer the term "true value," although others excoriate it as philosophically unsound.

We could also call the reference level a "target value." In a way this is a bad term because it implies that it is something we *want* to find through the measurement process rather than something we ought to find because, like Mt. Everest, it is there. Unfortunately our desires can influence our notion of what is true, and we can even unconsciously bring the latter into agreement with the former; my use of the term "target value" is not meant to imply that I think it legitimate to equate what we would like to see with what is there.



Precision is indicated by a multiple of σ'_P. $\bar{X}'_P - \bar{X}'_R$ is called bias.

Fig. 1.—Precision and bias.

On the other hand, "target value" is a suggestive term (hopefully, not overly so) for purposes of present discussion. It is, in fact, interesting to compare the measurement situation with that of a marksman aiming at a target. We would call him a precise marksman if, in firing a sequence of rounds, he were able to place all his shots in a rather small circle on the target. Any other rifleman unable to group his shots in such a small circle would naturally be regarded as less precise. Most people would accept this characterization whether either rifleman hits the bull's-eye or not.

Surely all would agree that if our man hits or nearly hits the bull's-eye on all occasions, he should be called an accurate marksman. Unhappily, he may be a very precise marksman, but if his rifle is out of adjustment, perhaps the small circle of shots is centered at a point some distance from the bull's eye. In that case we might regard him as an inaccurate marksman. Perhaps we should say that he is a potentially accurate marksman firing with a faulty rifle, but speaking categorically, we should have to say that the results were inaccurate.

Components of Precision and Accuracy

One school of thought on the subject of accuracy insists that if a marksman hits the bull's-eye "on the average," then he is accurate even though the man may have a wavering aim so that his shots scatter. The point is that accuracy in this sense is determined solely by the behavior of the long-run average of the shots. The position of the average shot is assumed, of course, to be the centroid of the bullet holes in the target: few shots might actually hit or nearly hit the bull's-eye.

The second school of thought on accuracy would insist that if the man is unlikely to be very close to the bull's-eye he should be termed an inaccurate shot. That is, the second school holds to the belief that accuracy should imply that any given shot is very likely to be in the bull's-eye or very near to it. Both schools of thought have meaningful and verifiable versions of the comparatives "more accurate" and "less accurate," although if one follows the second school of thought, such a comparison is not always possible.

We may regard the rifle-range rules, the specifications of the rifle, ammunition and target, and manual for marksmen as analogous to a test method; the marksman and his rifle firing away at a specific target, on a specific range, perhaps on a specific day, correspond to a measurement process. Likewise, it is easy to translate the difference in viewpoints with regard to accuracy just noted from the field of marksmanship to the field of measurement and testing.

Before going further, we had best put down some elementary notions that we intend to use with respect to the problem of precision and accuracy in measurement. The first of these is the long-run average of the measurement process, designated by $\bar{X}'_P$ (Fig. 1). It is assumed in this case that our measurement process produces a series of numbers and that therefore the quantity denoted by $\bar{X}'_P$ is a single real number. The reference level will be denoted by $\bar{X}'_R$. The difference between these two quantities is almost universally referred to as "bias." Some have used the term "systematic error" synonymously, but others prefer to regard systematic error as the cause of bias. Another notion of primary importance is the standard deviation of the measurements produced by the measurement process. For this we have the symbol, σ'_P, and we regard this as a long-run characteristic of the process just as we do $\bar{X}'_P$. In words, the definition of the standard deviation is the square root of the mean squared deviation of the measurements from $\bar{X}'_P$.

Definition of Accuracy

Now let us return to our debate about the definition of accuracy. It is impossible to say that one of these viewpoints is wrong and the other is right from a sheerly logical point of view. I can put forth an argument relative to the conservation of linguistic resources. It seems to me that the terms "bias" and "systematic error" are adequate to cover the situation with

which they are concerned. If, nevertheless, we add the term "accuracy" to apply again in this restricted sense, we are left wordless—at the moment at least—when it comes to the idea of over-all error. From the point of view of the need for a term it is hard to defend the view that accuracy should concern itself solely with bias.

It is also important to determine whether one or the other of these definitions of accuracy has practical advantages over the other. I feel that there are certain circumstances in which one may be preferred and certain circumstances in which the other may be preferred. I doubt that one could show that there are substantially more situations in which one of these is appreciably more suitable than the other.

We are then left with the problem: If we are to have a single recognized definition of accuracy, on what basis other than that of need will we choose between these two, assuming that these are the only two possibilities we wish to consider? It would seem that the only basis for decision is a consideration of how the term accuracy is now used. It must be conceded that the school that believes that accuracy should connote the agreement between a long-run average of measurement process and the reference level is one of long standing among some experimenters. It can be argued, too, that it is easy to use accuracy in this way, because it is then possible to measure accuracy in terms of bias or systematic error. On the other side, a paper by Churchill Eisenhart of the National Bureau of Standards[1] has had considerable influence. The Bell Telephone Laboratories have used accuracy in his sense for some years.

We can also look at what practices are being followed with respect to the use of the word "accuracy" in different ASTM standards. There are a negligible number of cases in which accuracy is explicitly described in ASTM standards as a property of the long-run average. Usually there is no clear statement of which concept of accuracy is intended. In most of the standards in which accuracy is mentioned or discussed, precision is not mentioned or discussed, and vice versa. While the meaning and usefulness of the exact quantities given may be open to question in some cases, the obvious intent of these statements with regard to accuracy is that of an all-inclusive notion of error of measurement. Incidentally, in some instances the term precision has been used with regard to over-all error of measurement. At least one ASTM paper has explicitly taken this same view of precision. Seldom is bias or systematic error singled out in this body of literature. Thus there is overwhelming evidence that we need a term at least for the concept of over-all error.

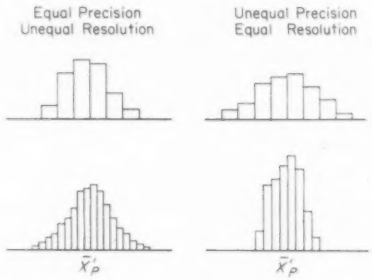


Fig. 2.—Resolution and precision (illustrated by frequency histograms).

On this basis I think there is considerable justification for the choice of Committee E-11 that accuracy should connote the idea of the error of individual measurements when that error is compounded of bias or systematic error and random or nonsystematic error.

Statistical Resolution

At this point I should like to inject one more note of confusion. It seems to me that one of the features of test methods which occasionally obtrudes itself in the arguments about definitions of precision and accuracy is the question of sensitivity and, as I shall call it, statistical resolution of measurement. Sensitivity sounds as though it ought to contribute to precision as we have described it. We could describe sensitivity as being measured by the minimum difference between the measurements of two different materials which we can possibly distinguish by the test method under consideration—the smaller the difference, the higher the sensitivity. Logically, if not conventionally, we might say that sensitivity should be the reciprocal of this quantity, but we shall follow the more conventional idea that sensitivity is directly measured by this minimum measurable difference.

At any rate, it is obvious that if our sensitivity is not very good, our precision is also not very good. However, the two are different, and we might define another quantity, to be called statistical resolution, which may be expressed as the ratio of sensitivity to standard deviation. If we can detect arbitrarily small differences in the property measured, the resolution is numerically small, because the sensitivity is small while the standard deviation is presumably a function of other factors as well which do not permit its magnitude to be arbitrarily reduced. Figure 2 exhibits some interesting distinctions that can be drawn. The left-hand pair of histograms in Fig. 2 have about equal spread, but the upper one is more coarsely grained, so to speak. Thus the sensitivity of a process producing the lower histogram would be greater than that of a process producing the upper one. Since the standard deviations are about equal, it follows that the resolution associated with the lower histogram is greater than that associated with the upper. On the other hand, if we spread the upper histogram out and squeeze the lower one together, as it were, without much change in the column widths, we should get something like the right-hand pair of histograms. The ratio of standard deviations would have been changed but not the ratio of sensitivities. If we spread and squeeze just the right amount, we can obtain equal resolutions although the sensitivities and standard deviations differ. This serves simply to emphasize that sensitivity is an absolute property and resolution a relative one in terms of the units of measurement. It may be useful to consider this kind of statistical resolution in measurement problems more than it has been thus far.

It may be perfectly possible that one process has higher resolution (numerically smaller) than another and yet is less precise. The number 2 represents a "worst possible" resolution, so to speak: it is that of a process in which we are able to observe either one or another of two values with equal probability. In general, we would expect the resolution of a process to be numerically smaller than 2. For practical purposes perhaps we should prefer resolutions on the order of $\frac{1}{2}$ or less.

Measures of Precision and Accuracy

Another purpose of the E-11 practice is to give a common set of terms for describing the measures or indexes of precision or accuracy stated in particular standards. This is not an easy job either. First of all, different fields have particularly favorite ways of expressing precision. Most of these measures are multiples of the standard deviation; it is not always clear which multiple is meant. It is possible, of course, that a single simple multiple might not do.

Some consider it unfortunate that precision should be stated as a multiple of standard deviation, since precision should increase as standard deviation decreases. Indeed, it would be more exact to say that standard deviation is a measure of imprecision. However, sensitivity, as we have previously

[1] C. Eisenhart, "The Reliability of Measured Values—Part I. Fundamental Concepts," *Photogrammetric Engineering*, June, 1952, pp. 542–554.

indicated, suffers from this logical inversion without hurt. Perhaps we can best avoid this by saying that standard deviation is an index of precision. The habit of saying "The precision is . . . " is deeply rooted, and there would be understandable impatience with the notion that standard deviation should be numerically inverted before being quoted in a statement of precision.

Some obvious choices of multiples of standard deviation for indexes of precision are given in Table I. The standard deviation itself, of course, may be used as an index. Sometimes the precision is stated as ± 2 standard deviations with the implication that approximately 95 per cent of all the measurements of the measurement process will fall within two standard deviations of the long-run average for that process, whether that long-run average agrees with the reference level or not. In some cases people have used the multiple 1.96 rather than 2 in the hope that they will have obtained limits which more truly represent actual bounds within which 95 per cent of the universe will lie. Usually such refinements are specious on two grounds: first, because the accuracy with which the standard deviation will be known is not consistent with distinguishing between mutlipliers of 2.00 and 1.96; second, too great a reliance on the figure of 95 per cent is unjustifiable, anyway, since some measurement processes will yield a universe of observations of which perhaps only 90 per cent may lie within the 2-standard-deviation limits. It is reasonable to suppose in most cases, however, that such limits will include 90 to 95 per cent of the statistical universe of observations. Because of the uncertainty associated with this multiple, it might usually be better avoided in favor of other alternatives.

Precision is often stated as ± 3 times the standard deviation, with the idea that for all practical purposes a measurement process, assumed to be under control, should be expected to yield measurements only within a 3-standard-deviation band about the long-run process average.

In some fields a preference has been shown for expressing precision not so much as a difference between an observation and the long-run average value of the measurement process but rather as a difference between any two observations from the same process. This has led to limits analogous to those previously mentioned and calculated from them by multiplying by $\sqrt{2}$. There is again a problem of giving such things names.

TABLE I.—INDEXES OF PRECISION.

Term	Reference Abbreviation	Notation
One-Sigma Limits	1S	$\pm\sigma'_P$
Two-Sigma Limits	2S	$\pm 2\sigma'_P$
Three-Sigma Limits	3S	$\pm 3\sigma'_P$
Difference Two-Sigma Limits	D2S	$\pm 2\sqrt{2}\sigma'_P$
Difference Three-Sigma Limits	D3S	$\pm 3\sqrt{2}\sigma'_P$

There are other distinctions to be made, however, which should be as clear as possible in any statement of accuracy. Frequently precision is stated as a percentage, such as the coefficient of variation. Any of the above indexes of precision can be converted to a percentage, but it is not altogether clear that there is only one figure of which these may be stated as percentages. Obviously the long-run average of the process is an outstanding candidate to use as a means of expressing percentage figures. However, this may not be convenient in all cases. In some areas it is not unusual to use a single fixed quantity of which precision is stated as a percentage.

Furthermore, the precision of a process may alter with the reference level regardless of the way in which we indicate the precision, whether as a standard deviation or a standard deviation expressed as a percentage of some other number. If that is so, the use of a single number on a standard then raises a question. Does this mean that the precision is constant over the range of reference levels in which we could possibly be interested or does this single figure of precision mean something else? Certainly it is not uncommon to consider this to be a maximum figure of precision over all possible levels of interest. If so, it would be well to append the word "max" after the stated precision of the process.

Again it is often desirable to qualify the statements of precision by some reference to the system of causes for which the statement of precision is valid. For instance, is this the kind of precision we should expect if we have one highly trained scientist operating one carefully adjusted instrument in a laboratory? Is it what we should expect over a short period of time or over a long period of time? Is it what we should expect of industry-wide comparisons of the same material? And so on. Such qualifying terms as "single operator," "interlaboratory," "single-day" are helpful to the interpretation of statements of precision. Perhaps even more important, thinking about these things is likely to be a big help in getting one to state the precision that he is really interested in in the first place. Sometimes we cannot succeed in being altogether explicit, but efforts to do so in this regard may very well help in the attainment of valid statements of precision.

TABLE II.—INDEXES OF ACCURACY.

Term	Reference Abbreviation	Notation
Precision and Bias	...	$k\sigma'_P$, $\bar{X}'_P - \bar{X}'_R$
Limits of Error	LE	$\bar{X}'_P - \bar{X}'_R \pm 3\sigma'_P$
Root Mean Square Error	...	$((\bar{X}'_P - \bar{X}'_R)^2 + \sigma'^2_P)^{1/2}$

What has been said of precision can be said also of accuracy with regard to the terms and clarity of reference. The particular measures used are somewhat more difficult to deal with. This is because we have used the definition of accuracy which involves the combination of random and systematic error. Perhaps the most satisfactory way of expressing accuracy is to express precision in some way and then also to state the bias in a comparable manner. Both these figures could be represented as quantities which may vary as the system of causes is altered in some respects. This and other possible means are set down in Table II. The root mean square of error has nothing in particular to recommend it except statistical history. It cannot be used in any simple straightforward way, nor is it much help in efforts to visualize the situation with regard to experimental error. It has been dropped from the practice.

Thus, we hope this practice may provide a way of interpreting consistently and exactly such statements as "the precision of the method is ± 2 per cent (relative per cent S.D.) max." Reference to this practice would, we hope, facilitate such consistent interpretation.

Verification of Precision and Accuracy

There is one very obvious problem, among others, which is not discussed at all in the recommended practice to be issued by ASTM Committee E-11. That is the problem of verification of the precision or accuracy of a measurement process. Anyone will acknowledge that assessing the precision or accuracy is a prerequisite to stating it. It is not so easy to see just how one goes about doing this. Other speakers at this symposium will discuss this subject. However, it is pointed out in the Recommended Practice that any such process of assessment is in itself a measurement process distinct from one that exists for the purpose of testing materials and evaluating them on a routine basis.

How to Evaluate Accuracy

BY W. J. YOUDEN

This paper presents a logical breakdown of the error in a measurement into (*a*) the systematic error inherent in the procedure, (*b*) the local systematic error of the laboratory using the procedure and, (*c*) the random error (precision). This breakdown should facilitate efforts to attain better accuracy. Several methods are given for identifying sources of error in measurements.

THE term accuracy conveys to most the idea of a value that is very close to the truth. The "truth" has to be defined rather carefully. Absolutely pure sodium chloride undoubtedly has a composition which conceptually, at least, corresponds to a certain weight per cent content of chlorine and a residual weight per cent of sodium. The presently accepted atomic weights for chlorine and sodium can be used to calculate the weight composition. This calculated result, admittedly, is not the absolute truth, but it has to serve in that role. A chemist, trying out an analytical procedure, will take this calculated composition as the truth.

Systematic Errors

Good agreement among repeat measurements in no way implies that the average of the measurements is close to the "truth" when the truth is some conceptual value of the property under measurement. Experience shows that averages of increasing numbers of repeat measurements, made under uniformly maintained conditions, do converge upon a particular value that reflects the true value but also depends in part upon the procedure, equipment, and environment used to make the measurement.

In the ideal situation, the limiting mean that the averages of repeat measurements converge to would be the same as the true value. The difference between the conceptual true value and the average of the measurements is an estimate of the systematic error associated with the particular procedure and the circumstances providing the measurements. If there is evidence of a systematic error when the procedure is used in several laboratories, then this systematic error may be taken as a property—undesirable—of the particular procedure.

Some care is necessary at this point. Again, experience shows that if a measurement procedure is used at different times and places, that is, in different laboratories, the measurements converge to different average values. These average values are often maintained for considerable periods for the different laboratories and reflect inevitable differences in reagents and in the calibration of instruments; also differences between localities in humidity, temperature, etc., and finally some possible differences in the interpretation of the instructions for making measurements. Every round robin results in a collection of laboratory averages that differ among themselves by more than can reasonably be accounted for by the within-laboratory precision. Some point of view needs to be adopted toward the collection of systematic errors that are available when a value acceptably close to the true value is available for comparison.

One convenient viewpoint, whenever enough laboratories are involved, is to designate the average of all the laboratory averages as a grand average, characteristic of the procedure. The difference between this grand average and the true value can be considered an estimate of the systematic error of the procedure. The scatter exhibited by the individual laboratory averages suggests that calibration errors, and all other departures from the norm, introduce positive or negative departures from the normal systematic error of the procedure. There are two important consequences of this point of view. First, the difference between a laboratory average and the true value is not regarded as a single item but rather as a composite of two items, namely, the systematic error of the method modified by a systematic error of the laboratory as measured from the grand average. The second consequence is that the systematic error of the laboratory, relative to the consensus of all laboratories, can be obtained even when the true value of the property is not known. Even when the true value is known, it does not seem fair to charge a test laboratory with the systematic error that is an inherent property of the procedure as shown by the consensus of all laboratories. A test laboratory should be held responsible only for departures from the performance that the procedure is capable of giving. The consensus of the laboratories seems a reasonable appraisal of the procedure.

There is another interesting consequence of the concept of the procedure average. Figure 1 shows the averages for a chemical analysis for each of nine laboratories marked on a scale of values. Also marked is the procedure average (grand average of all laboratories) and the assumed true value computed from the atomic weights. The procedure average is about 0.2 per cent above the theoretical composition, and this may

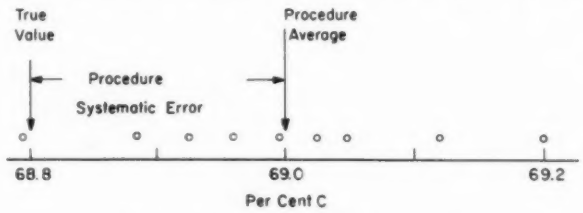


Fig. 1.—Averages for nine laboratories.

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W. J. YOUDEN's academic degrees are in chemical engineering and chemistry. He began to use statistical procedures in 1925 when he was appointed chemist at the Boyce Thompson Institute for Plant Research, Inc. He held this post for 24 years except for the war period when he served as operations analyst with the Air Force. Since 1948 he has been a statistical consultant in the Applied Mathematics Division of the National Bureau of Standards, Washington, D. C.. Mr. Youden is the author of more than 100 papers, has written a book (*Statistical Methods for Chemists*), contributed statistical chapters to several other books, and for six years wrote a column "Statistical Design" for *Industrial and Engineering Chemistry*.

be taken as an estimate of the systematic error of the procedure. The nine laboratories are scattered over a range of about 0.4 per cent. The lowest laboratory average is virtually coincident with the true value; the highest laboratory average is 0.4 per cent above the true value. Heretofore, the lowest laboratory (in this instance) would expect congratulations and the highest laboratory would be suspect. Quite the contrary interpretation can be made. There is no basis to consider either laboratory as doing better work than the other. Both laboratories have averages that depart by about equal amounts from the procedure average. Unless the low laboratory can describe some departure from the prescribed procedure to account for its result, no credit should be given for the accidental coincidence with the true value. Incidentally, if a departure from the procedure is admitted, this useful information should have been made available to the committee when the instructions were being prepared. Departures from the *procedure average* cannot be ignored. Indeed, unless and until a procedure has been adequately described, so that nearly all the laboratories show acceptable agreement for their averages, the question of agreement with a true value is hardly meaningful. If laboratories disagree, the procedure needs more careful specification. If the procedure average differs by an unacceptable amount from the true value, the procedure itself requires modification or rejection.

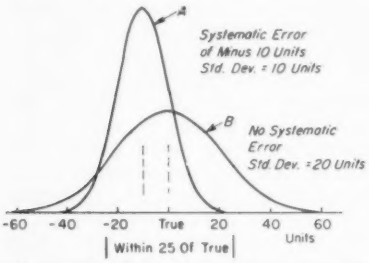

Fig. 2.—Which one is the more accurate?

It is worth noting that the usual evolution of a procedure does not suggest the viewpoint discussed above. Generally a particular laboratory works out a procedure and, because it gets highly satisfactory results, urges a trial by other laboratories. If this procedure happened to have been first tried by the laboratory that got the highest result in Fig. 1, perhaps nothing more would have been heard of the procedure. If the lowest laboratory in Fig. 1 was the first to try, then this laboratory becomes an enthusiastic sponsor of the procedure. One cannot escape the evidence that the laboratories are spread out and that any one of them might have been the originator of the procedure. There is a possibility that, for the sponsoring laboratory, a chance combination of instruments environments, etc. approximately canceled out the inherent systematic error of the procedure. Confusion will reign until the evidence is reviewed in the proper light. The procedure reported in Fig. 1 does have a systematic error as shown by the fact that eight of the nine laboratory averages have positive deviations from the true value.

Precision and Accuracy

There is much evidence that the systematic errors of laboratories, even when measured from the consensus, often tend to be as large or larger than the standard deviation computed for the random deviations associated with the precision. Even rather small systematic errors are fairly easy to demonstrate, because the random error of an average is inversely proportional to $\sqrt{n}$, where n is the number of measurements in the average. Consequently, a relatively few measurements stabilize reasonably well a laboratory average. In passing, it should be remarked that a much larger number of measurements are necessary to obtain a good estimate of the precision. Fortunately, the precision appears to be much the same for most laboratories using a procedure so that a pooled estimate of the precision is usually employed.

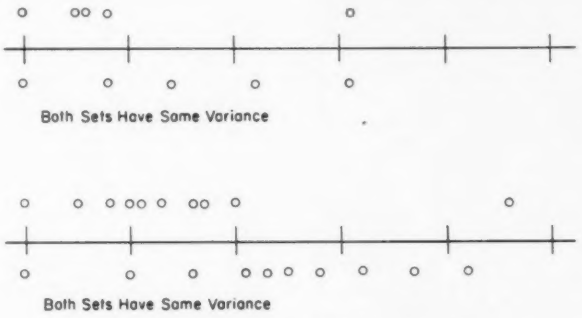

Fig. 3.—Variance does not tell the whole story.

One question is often raised. Is a procedure with a small systematic error to be preferred to one with practically no systematic error if the latter has much poorer precision? Suppose a precise procedure, A, with a standard deviation of 10 units has a systematic error of 10 units. Still, 93.3 per cent of individual results will be within 25 units of the true value. Another procedure, B, without systematic error, but with a standard deviation of 20 units, will have only 78.9 per cent of the individual results within 25 units of the true value. The error curves are shown in Fig. 2, and clearly more of the area of curve A lies within 25 units of the true value. So, on a single result, there is a better chance of an error less than 25 units using the procedure with the systematic error. Some writers have suggested that, from this point of view, A is the more accurate procedure.

This advantage of the more precise procedure does not always apply. Consider a manufacturer shipping many lots of his product. If the manufacturer is paid on the amount of active ingredient in his product, he will lose money in the long run using procedure A. His average will be 10 units lower than it would have been if procedure B, had been used. True, the results will fluctuate more with procedure B, but the losses and the gains will, in the long run, cancel out. This manufacturer no doubt would regard procedure B as the preferred procedure.

The Evaluation of Accuracy

There is no solution to the problem of devising a single number to represent the accuracy of a procedure. All through the preceding discussion accuracy has been associated with the test procedure rather than with the numerical measurement that results from using the procedure. The performance of the test procedure has to be established, and, barring evidence to the contrary, the measurements obtained by the procedure are considered to be subject to a particular systematic error and to have a particular precision. By various devices the systematic error may be allowed for. In routine work a reference specimen often permits the introduction of a correction that simultaneously adjusts for both the procedure systematic error and the local systematic error.

A more troublesome matter concerns the desire to attach to a reported result some statement of confidence limits for the result. The question is sometimes put in the form: What confidence limits apply to a result reported by a new laboratory not included in the original group participating in the study of the procedure? There is a pitfall here that will catch some who have uncritically accepted certain statistical techniques. One may glibly say that there is a certain within-laboratory

error and, in addition, a between-laboratories error that need only to be combined. The upper half of Fig. 3 shows two hypothetical sets of laboratory averages. Both sets have five laboratories, and both have the same between-laboratory variance. Nevertheless the two sets correspond to substantially different situations. In the set below the axis the laboratories fall into a reasonable pattern that might, conceivably, arise if the laboratory systematic errors were normally distributed. The set above the axis shows one extreme laboratory with the others compactly grouped and conveying a picture of a far more satisfactory *procedure*. More laboratories emphasize this contrast (Fig. 3, lower half).

In predicting what may happen if a new laboratory is included, statistical formulas lead to the same result for both sets. Few experienced laboratory workers will feel comfortable at this equivalence. More likely these workers would be inclined to get the extreme laboratory in the upper set to locate its trouble or else drop it from the group. Indeed, is it fair to judge the procedure with this laboratory included? The matter of confidence limits rests upon the presumption of a statistical distribution. Blind application of statistical formulas without thoughtful examination of the results may lead to absurd predictions.

The successful application of statistical methods rests upon a thorough understanding of the way the data were obtained. For example, a dozen repeat measurements made in close succession provide an estimate of the random variation to be encountered under such relatively unchanging conditions. If the dozen measurements are made one-by-one on randomly selected days over a period of weeks, the variation is usually larger. This additional component of variance can be merged with the within-day component. But if there is an awareness of a systematic error that applies to *all* the measurements, any well informed estimate of, say, the maximum size of this systematic error, must not be combined with the random component. Probability statements cannot be made about such combinations of random and systematic errors.

Detection of Systematic Errors

The differences so often found between the averages reported by several laboratories testify to the presence of systematic errors for at least some of the laboratories. Within one laboratory, other means are required to reveal any systematic error in the procedure. There are three major devices commonly used to test a measurement procedure:

1. Measurement of known materials.
2. Comparison with other measurement procedures.
3. Comparison with modifications of the given procedure.

More often than is realized a true value is known. All target shooting is a class of known values. The center of the bulls'-eye, or the assigned target coordinates in a bombing mission, is a known value. The objective is to hit the center of the target. The result of each aiming is a measurement usually reported directly as the "aiming error." Reflection shows that, given a collection of impact points, it will be more informative to locate, first, the centroid of the impact points. The displacement of this centroid from the assigned coordinates of the target corresponds to a systematic error, and the scatter of points about the centroid reveals the precision. Quite different steps will be needed to correct for the displaced centroid and to reduce the scatter about the centroid.

Often, in analytical chemistry, samples of known composition can be prepared. Spectrographic procedures are sometimes tested on materials analyzed by the more tedious and accurate "wet" methods of analysis. The "true" values thus established are often quite adequate for testing the spectrographic procedure. The standard materials prepared by the National Bureau of Standards are also used to provide materials with known "true" values.

Experimenters have long felt more at ease when two or more quite different procedures show agreement. Agreement does not prove the absence of a systematic error, but it does constitute evidence against the presence of a systematic error. Analytical chemistry offers many opportunities to try, on the same material, two or more analytical procedures that differ in the chemical reactions and reagents involved.

Another method, not used as often as it might be, makes use of a proportional relation when this exists. Consider a stock of material submitted to analysis. If several samples each weighing 2 g are analyzed, good agreement does not rule out the presence of a systematic error in all the results. But if samples of 0.5, 1.0, 1.5, 2.0, and 2.5 are tested, the weights of precipitate, or the volumes of reagent used should be strictly proportional to the sample weights. A straight line through the origin should fit the points if the observed results are plotted against sample weights. If there is a systematic error, constant over the range of sample weights, the points will be fitted by a line that intercepts the y-axis at a point corresponding to the systematic error. If the systematic error is proportional to the sample weights, the line will still go through the origin and the systematic error will not be revealed.

Test procedures for many materials lead to results which are not invariant under, for example, changes in specimen dimensions. Extremely careful specification of the test specimens is then necessary. The results are considered to be closely correlated with important properties of the material in bulk. Thus a cube of cement 2 in. on each edge may be submitted to a compression test. The results of such tests are used to determine whether the product meets certain specifications. Compression tests on cubes 3 in. on each edge could also be used, but, presumably, the relation of breaking load to cube dimensions is not a simple one.

Refined measurements of certain physical constants usually have systematic-errors considerably in excess of the precision error attached to the average. Here an extremely carefully constructed set of equipment tends to give a series of readings showing superb agreement. Later, another worker, with an entirely different ensemble but based on the same principle, obtains an average unquestionably displaced from the results of preceding workers. Standard practice calls for the most painstaking elimination of sources of systematic errors often by introducing various corrections. Suppose, in the equipment, a tube of 1 mm in diameter is needed. An estimate will undoubtedly be made of the uncertainty introduced in the final result by the estimated uncertainty in the tube diameter. Surely the use of a second similar tube, or even one somewhat bigger or smaller, will provide an opportunity to estimate the effect of uncertainty in the tube diameter.

Experimenters immediately object that such dualization of each part of the apparatus would vastly increase the program. That is true. It is also true that a later investigator usually changes nearly everything. He gets a somewhat different result and there is no way to locate the reason. If the first man had tried two diameters of tube, and the second worker tried some other alternatives, then eventually there would accumulate the necessary information to pin down the source or sources of discrepancies.

Detection of Errors by Designed Experiments

Testing laboratories that run many tests of the same kind often overlook opportunities to check up on their

TABLE I.—SCHEDULE FOR PLACEMENT OF BARS.

Comparison Number	Bar Position East	Bar Position West	Difference, East-West	Comparison Number	Bar Position East	Bar Position West	Difference, East-West
1.....	A	B	d_1	6.....	A	C	d_6
2.....	B	C	d_2	7.....	C	E	d_7
3.....	C	D	d_3	8.....	E	B	d_8
4.....	D	E	d_4	9.....	B	D	d_9
5.....	E	A	d_5	10.....	D	A	d_{10}
	Total.....		Σd		Total.....		Σd

equipment without in any way interfering with their regular program of work. Two examples will be given, one a precision procedure and the other a more approximate measurement.

Meter bars are sometimes compared by placing them end-to-end in a long chamber. Every effort is made to maintain a uniform temperature the length of the chamber, otherwise spurious differences in the lengths of the bars may be introduced. Careful measurements are made to check on the uniformity of the temperature. The bars are intercompared in sets, every bar being matched with every other bar. A set of five bars makes possible ten pairings and consequently ten comparisons. Each comparison leads to a difference in lengths between the two bars in the chamber. Let one end of the chamber be designated the east end and the other end the west end. If the various pairs of meter bars are placed in the chamber without any plan, an opportunity for an easy test of the equipment will be lost.

One device long used to compensate for position effects is to reverse the positions of the objects and repeat the measurement. An alternative device achieves the same effect without actually reversing the positions for each pair. The objects may be scheduled for the positions so that, over the total of all the pairings used, each object will occupy each position the same number of times. The schedule shown in Table I has been used for this purpose. The letters, A, B, C, D, and E are used to identify the bars and the d's with subscripts denote the observed differences, the difference always being the length of the bar in the east end of the chamber minus the length of the bar in the west end.

Examination of the schedule (Table I) shows that the placement of the bars the chamber is such that, for the first five comparisons, all five bars have been in the east end and the same five bars also in the west end. When the five differences are summed this amounts to subtracting the total length of the five bars from the total length of the same five bars. The sum of these five differences should, therefore, be zero, within the limits of the measurement error. Suppose, however, that one end of the chamber is persistently slightly warmer than the other end. This will increase the length of the bars in the warm end and introduce a small bias in every observed difference. The sum of the five differences provides a very sensitive measure because the total length of all five bars is involved. The second set of five comparisons provides a check on the first result.

Two advantages accrue from such a planned assignment of bars. First, a temperature gradient may be detected or, it the sum of the differences is satisfactorily small, the evidence of position equality has been provided at no cost. Second, if there is a position effect the correction of the observed differences using the estimate of the systematic error, $\Sigma d/5$, is a simple matter.

Consider a piece of equipment with eight test positions. Perhaps duplicate specimens are usually run. In any event duplicate specimens of each test material will be needed for the 28 materials tested in the program in mind. With duplicate specimens and eight test heads, four materials can be compared in any run. Comparisons among materials, within a run, rely on the equivalence of the various test positions. The choice of the two positions assigned to the duplicate specimens can be used to throw light on the equivalence of the eight heads. Number the heads 1 to 8, the runs by Roman numerals, and the 28 materials by $a, b, \ldots, z, A, B$. The schedule for the assignment of duplicates of these 28 materials is shown in Table II. Each pair of duplicate specimens provides a difference. These differences should be entered in Table III by placing in each cell the difference obtained by subtracting one duplicate from the other in the order indicated. For example, material a tested in the first run gives the difference between positions one and five. Thus, in the first column the differences are obtained by subtracting from the result obtained on head 1 the appropriate results obtained on the other heads. The first-row entries list the same values with opposite sign.

The totals at the foot of the columns when divided by 8 rank the eight heads with reference to zero. As an arithmetical check, the sum of the eight column totals must be zero. A statistician's help will be useful in a complete analysis of these data. The experimental design presented here is intended to fit into the regular testing procedure with a minimum of interference. A simple direct way to compare the heads, in a special test, is to use eight specimens of the same material in a single run. About four such runs will be required to obtain as much information regarding head differences as is here obtained with 28 pairs of duplicates.

TABLE II.—SCHEDULE TO TEST EQUIVALENCE OF MACHINE HEADS.

Run Number	Head Number 1	2	3	4	5	6	7	8
I...	a	b	c	d	a	b	c	d
II...	e	g	g	e	h	f	f	h
III...	i	j	k	l	j	i	l	k
IV...	m	n	m	n	o	p	o	p
V...	q	r	s	t	s	t	q	r
VI...	u	u	v	v	w	w	x	x
VII...	y	A	B	z	z	B	A	y

TABLE III.—ARRANGEMENT OF DUPLICATE DIFFERENCES TO EVALUATE THE HEADS.

Head Number	Head Number 1	2	3	4	5	6	7	8
1.....	...	2–1	3–1	4–1	5–1	6–1	7–1	8–1
2.....	1–2	...	3–2	4–2	5–2	6–2	7–2	8–2
3.....	1–3	2–3	...	4–3	5–3	6–3	7–3	8–3
4.....	1–4	2–4	3–4	...	5–4	6–4	7–4	8–4
5.....	1–5	2–5	3–5	4–5	...	6–5	7–5	8–5
6.....	1–6	2–6	3–6	4–6	5–6	...	7–6	8–6
7.....	1–7	2–7	3–7	4–7	5–7	6–7	...	8–7
8.....	1–8	2–8	3–8	4–8	5–8	6–8	7–8	...
Total.....	Σ_1	Σ_2	Σ_3	Σ_4	Σ_5	Σ_6	Σ_7	Σ_8

Summary

The number of test procedures grows daily. The variety of equipment defies enumeration. Always the question of the sources of variation arises when test results show poor agreement. The written instructions for conducting tests contain phrases such as "shake vigorously," or "clean thoroughly." Operators will vary in the way they follow such instructions. Often no effort has been made to ascertain how vulnerable a test procedure is to moderate variations in the actual manual operations involved. Usually, if some major source of experimental variation can be located, steps may be taken to improve the situation. Fortunately, for every interesting test situation some equally interesting experimental design can be devised to throw light on the sources of experimental source. As these sources are identified and corrected the accuracy of test results will likewise improve.

How to Evaluate Precision

BY W. S. CONNOR

THIS paper covers one aspect of how to evaluate the precision of a test method by comparing the results from several laboratories. A common procedure for carrying out such a comparison is to distribute some specimens of experimental material to each laboratory and to have the laboratories test the specimens according to the test method. Then the results of the laboratories are compared. The variation among the average results for the laboratories is a measure of the precision of the test method when carried out by different laboratories. The variation among the results for the specimens tested by a particular laboratory is a measure of the precision of the method as applied within that laboratory.

In some interlaboratory tests, the variation observed among specimens tested within a laboratory is due almost wholly to the variation in the material itself and not to failure of the laboratory to apply the measurement process in a reproducible way (though possibly in a way different from that of the other laboratories). For this case, I want to discuss how to report the average for a laboratory. What is usually done is to report the observed average, together with limits of uncertainty, which are intended to reflect the variation that would be observed among averages if the laboratory were to test other similar sets of specimens. The limits of uncertainty often are calculated by statistical techniques which may not, in fact, quite fit the situation that we are considering. I want to point out the assumptions that underlie these techniques, and to examine how well, or poorly, they are met in the actual situation.

We may suppose that there are N specimens of material which are distributed at random to each of k laboratories, so that each laboratory receives $N/k = n$ specimens. The values of the characteristic measured are

$$\mu_1, \mu_2, \ldots, \mu_N$$

for the N specimens, and the average value is

$$\mu = (\sum_{i=1}^{n} \mu_i)/N \ldots\ldots\ldots\ldots (1)$$

The n specimens which a particular laboratory receives will have values

$$x_1, x_2, \ldots, x_n$$

which are some subset of the μ's. In order to judge how near the average

$$\bar{x} = (\sum_{j=1}^{n} x_j)/n \ldots\ldots\ldots\ldots (2)$$

is to μ, it is customary to calculate confidence limits of the form

$$\bar{x} \pm c.$$

One frequently used formula is

$$c = ts/\sqrt{n}, \ldots\ldots\ldots\ldots (3)$$

where:

$$s^2 = \sum_{j=1}^{n} (x_j - \bar{x})^2/(n-1)$$

and t is the appropriate point of the t-distribution with n-1 degrees of freedom.

The assumptions that underlie this technique are that the random variables X, of which the observed x's are particular manifestations, (1) are normally distributed, (2) are statistically independent, and (3) have the same variance.

As a matter of fact, for the interlaboratory program considered, only (3) is true. The variables are not normally distributed, and the correlation between any two variables is $-1/(N-1)$, which implies that they are not statistically independent. We may inquire as to what effect this has on the use of Eq 3.

One effect is that the variance of the average, $\bar{X}$, is reduced by the multiplicative factor $(N-n)/N$, so that c should be written as

$$(ts/\sqrt{n})\sqrt{(N-n)/N} \ldots\ldots\ldots (4)$$

Luckily, the impact of the failure of assumption (1) to be realized is softened by the fact that $\bar{X}$ is "approximately" normally distributed. The closeness of the approximation depends directly on how nearly normal the distribution of the μ's is, and on how large n and N are.

The ideas developed here can be illustrated adequately by the study described by Horowitz and Connor.[1] In that study, the sodium hydroxide method was employed to determine the wool content of part wool blanket material. Determinations on different samples taken from the same batch and loom had an estimated standard deviation of 1.15 per cent wool, whereas repeated determinations on the same sample had an estimated standard deviation of 0.39 per cent wool. The variability among samples, assuming no analytical error, is estimated to be

$$[(1.15)^2 - (0.39)^2]^{\frac{1}{2}} = 1.08 \ldots (5)$$

Accordingly, the principal source of variability is among the samples, so that Eq 4 applies.

[1] E. Horowitz and W. S. Connor, "Variability of Wool Content in Part Wool Blankets," ASTM BULLETIN, No. 208, Sept., 1955, p. 42.

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On the Analysis of Planned Experiments

By MILTON E. TERRY

Over the past decade, scientists and engineers have increased the scope of their experimentation and the volume of test data to such an extent that additional analytic and reduction techniques have been required. With automatic data recorders of analog and digital types becoming almost commonplace, and with continuing enlargement of the body of scientific knowledge, it has become increasingly difficult for an experimenter to extract a satisfactory amount of information from his experiments.

The experimenter is finding himself more and more in the situation of the manufacturing or process engineer with far more data than he can ingest, digest, or understand.

It is not surprising, then, that several statisticians have returned to the pattern concepts of Shewhart and the other engineers interested in control of processes. Tukey and Anscombe,[1] and others have proposed several distinct and ingenious graphical techniques appropriate to various aspects of data analysis. Presented here are the technique and concepts I proposed and described.[2] This choice is personal and not dictated by scientific demand.

Over the past 30 years, two theoretical approaches to the statistical treatment of research and development problems have evolved. It is the purpose of this paper to show how both can be used together in the analysis of data.

W. A. Shewhart[3] and others have considered the problem of analyzing process data where the number of measurements is large. The approach proposed by Sir Ronald A. Fisher is to select a group of variables and a set of values of each variable, and then take measurements at selected combinations of these values. Then an estimate is made of the effect of changing each variable among its selected values, this effect being averaged over the selected values of each of the other variables. Randomization is used to average out the effects of the variables not under study.

The Shewhart method of analyzing data uses graphical methods wherein the data are first plotted in the pertinent recorded order in rational subgroups, and the applicable control limits found from an average "within-subgroup" estimate of dispersion. A subgroup central value and a dispersion estimate are plotted on charts together with their appropriate control limits. It is then standard practice to scrutinize all the charts for evidence of nonrandomness and lack of control. When the data finally pass all the tests of interest, estimation is justified. Of course, all datum points and statistics not satisfying a test criterion must be examined carefully by the research team for assignable causes. When the process yielding the data is not in control, estimation and prediction are hazardous.

Shewhart has pointed out that one may find sets of data which satisfy all simple statistical tests but display recurrent patterns which cast doubt on any hypothesis of randomness and independence. One of the most common

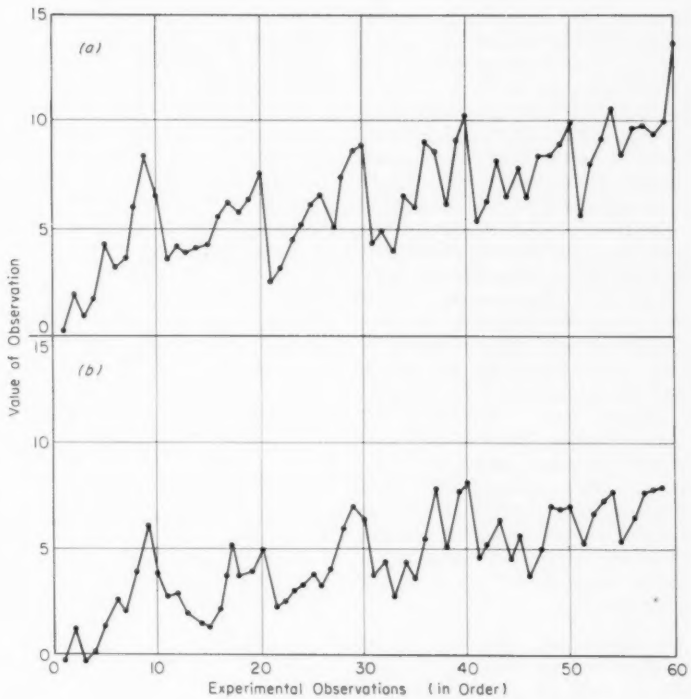

Fig. 1.—Experimental observations.

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[1] F. J. Anscombe and J. W. Tukey, "The Criticism of Transformation," unpublished manuscript, 1954.

[2] M. E. Terry, "On the Analysis of Planned Experiments," *Transactions*, Am. Soc. Quality Control, pp. 553–556 (1955).

[3] W. A. Shewhart, private communication.

patterns he has found occurs in the field of multiple readings, forming trend lines of varying length and magnitude of slope, with sharp breaks between segments. When the variation of these lengths and slope magnitudes is small, certain inferences can be made. When the variation is large, it is not clear what inferences should be made or with what confidence.

The analysis of a statistically designed experiment using the classical form of the analysis of variance depends on three basic assumptions of (1) additivity of treatment effect, (2) independence, and (3) homoscedasticity. Under these assumptions it is possible to incorporate into almost all research projects a schedule of measurements on specified elements of the experiment involving the selected variables in such a way that the effects of each selected variable averaged over the combinations of selected values of the remaining variables can be measured. In addition, the reality of effect from a selected variable can be tested *statistically*. In fact, the testing of apparent reality of effect and estimation of residual variation have been the main functions of the analysis of variance, and until recently were considered a satisfactory ending to the reduction of experimental data. Hence, some engineering and industrial research personnel have cast aside the statistical design of experiments, since they could neither satisfy all of the assumptions nor accept the classical form of the analysis of variance as satisfactory at the end of most experiments where several or all of the following questions must be answered:

1. Are there any *assignable* causes of variation present other than those introduced into the experiment deliberately?
2. How important are the effects of each of the selected variables?
3. Was the experiment well conducted?
4. Were there any unusual outcomes worthy of study?
5. How large a fluctuation can be expected in the process for manufacturing a product of which the experimental units were originally presumed representative?
6. What specifications can be written?
7. Which of the selected variables have effects demonstrated by this experiment not to be zero?

The control chart technique gives answers to these questions, but not all have the same efficiency. The analysis of variance originally seemed to be designed to answer question 7 only, but with the aid of recent developments (components of variance, multiple comparisons, and the analysis of residuals) now offers reasonable answers to the remaining questions.

Under the assumptions of a statistically designed experiment we can always state a mathematical model. Consider the following hypothetical simple experiment. We wish to study the effect of reducing corrosion by evaporating a metal p mils in thickness on an electrical element. Ten elements at each of six thicknesses ($p_1, \ldots, p_6$)

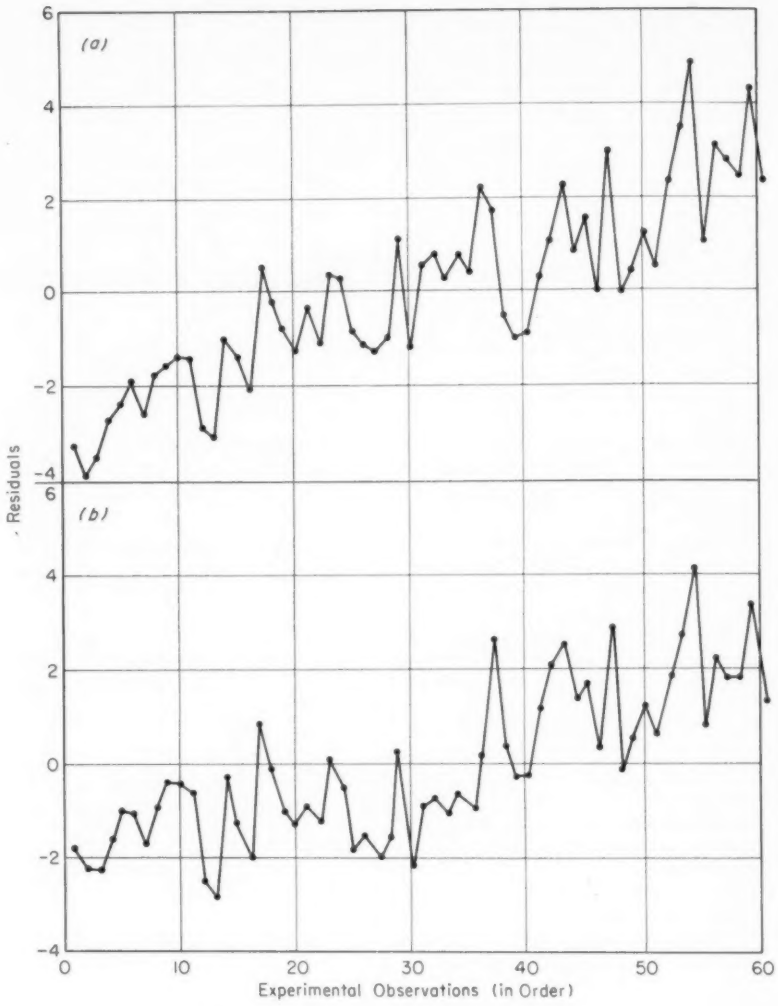

Fig. 2.—Residuals in order of manufacture.

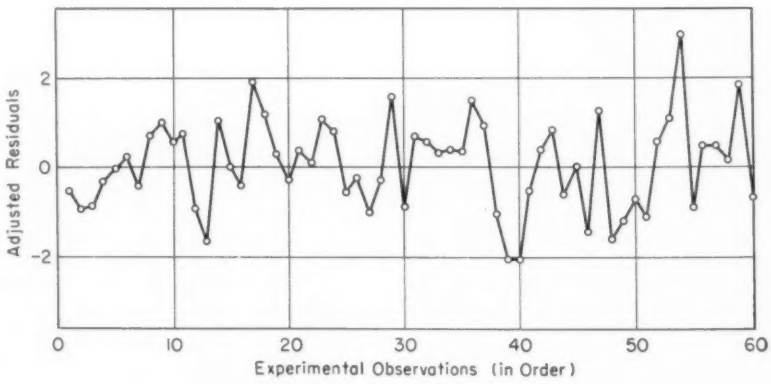

Fig. 3.—Adjusted residuals.

are considered necessary. Only one element at a time can be coated, so the 60 units will be processed in a random order. They are to be subjected to a controlled corrosion attack and then measured. Let t_i be the true relative effect of thickness p_i in reducing corrosion ($\sum_{i=1}^{6} t_i = 0$). Let μ be the true average corrosion effect over the experimental range and y_{ij} the measurement of the jth element with the thickness coating p_i. Then our mathematical model is

$$y_{ij} = \mu + t_i + e_{ij}; \qquad \begin{matrix} i = 1, \ldots, 6; \\ j = 1, \ldots, 10 \end{matrix}$$

where e_{ij} is the residual effect and is assumed to be a random independent normal variate.

We can estimate μ by the over-all mean $\bar{X} = SSy_{ij}/60$; and t_i by $\bar{X}_i - \bar{X}$, where $\bar{X}_i = Sy_{ij}/10$. Then we define $Y_{ij} = \mu + t_i$, $(i = 1, \ldots, 6)$ to be the predicted value, and $z_{ij} = y_{ij} - Y_{ij}$ to be the *residual* of the measurement ij. It follows that $\sigma^2 = \sigma^2_{z_{ij}} = S^2_{z_{ij}}/54$.

We stimulated this experiment by assigning constants to the μ and t_i and values to the ϵ_{ij} from a table of random order. In two simulations with respect to the ordered y'_{ij}, a linear trend and an abrupt shift in level were superposed respectively on the y'_{ij} to yield two sets of data y_{ij} of known behavior (see Figs. 1 (*a*) and (*b*)). Standard analyses were run. The estimates of relative mean effect were not very biased, but the estimates of the residual variation were so bad that no conclusions about equality of effects could be drawn. Then the z_{ij} were calculated for each simulation and plotted against order (see Figs. 2 (*a*) and (*b*)). When the data of Fig. 2 were corrected for the fitted trend line, the new estimates of the known parameters were excellent. The use of Fig. 3 gives an excellent estimate of the shift in level, and again correctly adjusted the estimates from Fig. 2

When the set of residuals, z_{ij}, constitute a time sequence, they can be plotted as such. In many engineering experiments, only one fabricating or measuring device is available, and hence one or more time sequences are imposed on the experiment. In general the statistical design will average out the time effect in the estimates $\hat{t}_i$ by randomizing the order of fabrication or measurement of the experimental units.

In a real sense, the set of residuals plotted against time, together with control limits, $\pm k_{\sigma_{\text{residual}}}$, are a control chart. Hence we are tempted to use the usual chart techniques. Since there may be constraints imposed by the model, the significance levels may be no longer identical with the tabular values. But when the control limits are used as action limits, satisfactory results should ensue.

Anscombe and Tukey have proposed plotting the set of residuals, z_{ij}, against its associated predicted value, Y_{ij}, when the experiment contains at least a double classification. Here "nonadditivity is shown by a curved regression. Nonconstancy of variance is shown by a wedge shape."

In general, plotting residuals both against their predicted values, and against serial order, s, enables the experimenter to examine that portion of his measurements which is not attributable to the suspect variables. He will have visual evidence as to the vexations from many sorts of nonadditivity of effect, nonconstancy of variance, linear trends, cycles, and wild shots which may be embedded in his experiment. Hence, the analyst-experimenter can take the necessary action to ensure that the final accepted readings in the proper units satisfy the assumptions on which valid predictions and estimates will be made. This form of analysis, used in conjunction with the analysis of variance, enables the user of a statistically designed experiment to focus the same type of scrutiny on his data that the control engineer can give to process data.

GENERAL DISCUSSION

MR. R. B. MURPHY (*author*).—My first comment concerns the term systematic error. I agree with Mr. Youden that bias may also be called systematic error. I think a person's professional field is likely to determine his preference regarding terms. Survey sampling people tend to use the term bias. Systematic error is an acceptable synonym. My remark about systematic error being sometimes used to denote the cause of bias was not meant to deny that. I find that people who are concerned with censuses, market research, etc., abhor the term "true value." People in physical sciences are not so likely to.

If accuracy is used in an over-all sense, it is preferable to distinguish between systematic error (or bias) and precision. It would admittedly be very difficult to make the qualification that one thing is more accurate than another, since you are dealing with at least two numbers. If you had two processes and one had a smaller standard deviation than the other as well as a larger systematic error, you could not usually say which process is more accurate.

Finally, I should like to remark on Mr. Terry's discussion of control. I most emphatically did not intend to give the impression that the measurements of a process *must* be "in statistical control." The whole procedure followed by Mr. Terry and his colleagues implies confidence in the general validity of the test method used; they feel that this procedure is capable of yielding meaningful results if you look at them with the right type of eye glass, and of course, the right eye glass is very necessary. How you find the eye glass is not so easy. However, the fact is I think that he exhibited a process considered capable of control in my sense, because his people dredged out the wild shots, even though it took a lot of work.

MR. W. S. CONNOR (*author*).—One point I should like to raise has to do with something that has interested me for a long time. It first came to my attention while I was with the National Bureau of Standards. I found in talking and associating with people doing experimental work that they were continually arriving at their plus-and-minus figures by methods which remain mysterious to me. This was done by more than just looking at the precision as estimated by repeated measurements, as we have talked about today. They would do that, and then in addition, they would make other corrections. They all entered the plus-or-minus figures. I should like some further light on this point.

MR. W. J. YOUDEN (*author*).—The experimenter does develop judgment about his methods of measurement. He will often quickly detect when his apparatus has developed

trouble. This is unsatisfactory to us who get our estimates only from taking his data. He tends to give us usually a very small set of data and he has years of experience.

He also, I think, is often rather optimistic about his errors, and this causes some troubles too. It leads rather naturally into Mr. Murphy's remark about sensitivity and resolution. Sensitivity, as I gather, refers to the smallest unit in which you can record a measurement. Maybe you can estimate, when you are reading a voltage, down to 0.1 mv. Now this is fine and desirable, particularly if your standard deviation is on the order of a 1 or 2 mv. Trouble develops when somebody says, "Well, I have a large standard deviation, there is no use recording to 0.1 mv," and consequently he throws away some sensitivity. I only remind you that almost all men are two meters high to the nearest meter, and with this information you lose all information about the variability of men's heights. This is one of the commonest errors—to throw good information away thinking there is nothing there. Well, that very variability is the breath of life to the statistician in statistical techniques.

I am also impressed with Mr. Murphy's emphasis that we must try and keep the component parts, the precision measure and the bias measure, separate when you make a report. It is tempting to want to have a single number, but quite different steps are involved in improving the precision and in removing bias. A marksman whose shots bunch together tightly, but are all to the right and below the bulls-eye, has one problem, and the man whose center of gravity is pretty close to the bulls-eye but whose shots are dispersed widely has another problem, and the man who has some of both has to cope with both of these problems. An attempt to use only one figure really obscures and loses information. I have long ago determined in the Bureau of Standards to let men use probable error, average deviation, standard deviation, range, or what they will, provided they will only be ever so explicit and describe exactly what they are using and how they got it. That would be a great victory in itself. There are far too many reports in which a plus-or-minus figure is entered and you do not know whether it applies to a single measurement or to an average; you do not know how he computed it—whether he was a probable-error man or a standard-deviation man or a two-sigma-limits man. If you are going to put a plus-or-minus figure down, please tell us how you got it.

Mr. Milton Terry (*author*).—I am going to take some of the comments that Mr. Youden has just made in reverse order.

He commented on the individuals who glibly and happily throw away information on measurements. I am more appalled at my friend who is measuring low-temperature responses, down to about 2 K, where the best he can get are three meaningful digits; but at higher temperatures he starts to get four, and at a little higher temperatures he gets five, so he very carefully plots the data on the finest graph paper he can get, draws in a smooth curve, reads this curve, and hands me the derived data all with five fancy digits and wants me to do some evaluation.

What have I now? I may have his smoothing function.

The next thing we can talk about with some feeling of hope, when the experimenter carrying out the experiment is an engineer, or a physical scientist, say, who is of known repute and known interest. More and more industrial laboratories, however, are using youngsters with two years of technical institute training on the bench, at the oscilloscope or pipet, and these young people are actually carrying out the experiment. Now here is where life really gets gruesome, because these data takers do not all have the same incentive to come up with sound and reliable answers. They may on occasion fudge things.

If it is a question of measurement of reference value for a single operator, then I would like to know whether that operator represents the universe of operators for which this specification or procedure is going to apply.

Mr. George Shombert, Jr.[1]—I would direct this remark to Mr. Terry.

A group of chemists in ASTM Committee D-27 on Electrical Insulating Liquids and Gases conducted a round-robin on a new method for the measurement of inorganic chlorides in askarels, and I was given the data to analyze. Now this method was considerably improved over previous ones, and (entirely apart from any question of bias or dispersion) we wanted to know how "*finely*" we could measure—how many figures to the right of the decimal point.

The test consisted of a titration, so there was a calculation to be made involving number of milliliters, normality, etc., and of course, this calculation could be carried out to any number of figures.

When the calculations were carried out to three decimal places (thousandths of a part per million) the results of the experiment looked quite hopeless and discouraging. Rounded off to hundredths, they become a very nice set of figures, susceptible to ordinary methods of analysis. If the results are rounded off to tenths, then, as Mr. Youden mentioned, you lose all the variations. It looks as though the data are telling me that the calculation should be carried out to hundredths.

I had this problem, and this is the way I solved it. I am not familiar with any discussion of this problem in the books that I have read. I wonder if any work has been done on it, or if there is any better way to attack it.

Mr. Terry.—I think Sutton Monro of Lehigh University has talked on this point of excessive numbers of digits and various techniques in investigating it, I do not know of anything having been written about it.

There is also the very real problem that comes when someone starts multiplying the original measurement by some constant correct to many decimal places. Now life becomes incredibly difficult. We have had this problem in measuring relays and the rebounds thereof where the measurements are the number of lines on an oscilloscope that is crossed by a pip. Then this is multiplied by 0.013476, say, and reported as mils of rebound. I defy any statistician to come up with a reasonable answer based only on the garbage that this produces, Whereas if you have the original number of lines crossed, you can make a great deal of sense out of the data. You begin to have an idea of how carefully this oscilloscope operator is reading the measurements, and you may find he reads it to the nearest quarter of a gap or the nearest half gap. But this constant that gets pushed into the data can obscure things badly. In your case I would be very interested in what was the derived process for transforming the raw data; what did this do?

Mr. Youden.—I think most of the time we try pretty desperately to create a situation in which we minimize bias problems. Round-robins are undertaken to bring different laboratories into reasonable harmony. If you do find one laboratory far out of line, that laboratory presumably will explore what it is doing and find out why its results are consistently high or low as the case might be.

If that laboratory believes itself right and all the others wrong, it carries the burden of proof. While it is possible that it is right and everybody else is wrong, I think the burden of proof is on that laboratory to determine, if it can, why its results differ from the consensus of the others.

Most of us then are content if we can get agreement among laboratories, be-

[1] Assistant to Works Manager, Pittsburgh Works, Allis-Chalmers Manufacturing Co., Pittsburgh, Pa.

cause then we can conduct business with each other, buyer and seller are happy. It really does not matter whether we are right or not as long as we do not quarrel. But when we come into the world of pure science, we want to be right, and if we are trying to determine the acceleration due to gravity or the velocity of light, extraordinary efforts are directed to removing these possible biases. What happens is that the experimenter himself, who has been doing the work, realizes that certain dimensions are critical, and undertakes to figure out what effect these would have on the result. He will then set some sort of upper limit to the amount by which he might be off. It is certainly a good thing for him to list such possible disturbances and to indicate whether they are presumably of one sign or the other, and put it on the record as a guide for future experimenters.

There is no substitute, finally, for trying the experiment in a different way, and, as I think Mr. Connor has properly emphasized, seeing if you can come out with about the same value. But in the world in which most of the people here are concerned, we want to get agreement among ourselves, and when we find disagreement among laboratories in a round-robin, we are concerned with the precision. We might just as well face up to it that we must always expect a little more scatter among the laboratories than you would anticipate on the basis of precision. It is just inherent in the nature of things. But if you can find discrepant laboratories—really discrepant—then the way is open to take some action, and such a laboratory, if necessary, can visit some typical laboratory that belongs in the consensus and explore its way of making the test.

Really, we would be content in most cases if we could all achieve the same relative bias, because then we would be in agreement. Later on, when some pure scientist has enough time to refine the method and remove the bias, or when the Bureau of Standards gets around to making a standard sample that all men can adhere to, then this may call for an adjustment, but we will all move together. I think we worry too much about knowing the absolute bias, what we are really worried about most of the time is that our relative biases are different.

MR. CARLOS J. HILADO[2]—I should like to direct this question to Mr. Murphy. This discussion started with the discrepancy over the use of the terms precision, bias and, accuracy. Is it in the province of ASTM Committee E-11 on Quality Control of Materials to enforce this at least as far as ASTM is concerned?

MR. MURPHY.—I do not see how I could answer yes to that question. So far as I know the only power that a document of this kind has is that of persuasion.

MR. HILADO.—Do you have an official recommendation for the definitions which have been put forward today, especially the proposal that the term accuracy be used to cover both bias and precision?

MR. MURPHY.—We do not have it in final form. I had expected it would be by this time, but the reason it is not has nothing to do with the issue of whether accuracy should be a term to cover both precision and bias.

I expect that when the practice comes out it will contain this proposal, but at the moment the practice is still being edited. It has passed through its task group, and when it has been revised, it is expected that a vote of the whole committee E-11 will be taken. We hope that vote will be favorable.

[2] Research Chemical Engineer, Union Carbide Chemicals Co., South Charleston, W. Va.

Discussion* of Paper on Fracture Testing of High-Strength Sheet Materials[1]

MR. F. A. MCCLINTOCK.[2]—The report of the Committee on Fracture Testing of High-Strength Sheet Materials presents an interpretation of test results that is based on the elastic distributions of stress around a crack. But relatively large areas of plastic deformation may be present around the tip of a crack, especially at the high stress levels often encountered in practice. A better understanding of experimental results may therefore be obtained from an elastic-plastic stress analysis. The principal advantages of an elastic-plastic analysis are: (1) it shows why cracks that are initially stable become unstable, (2) it relates the notch sensitivity to other physically measurable quantities, and (3) it highlights the value of describing the notch sensitivity in terms of the critical radius to the elastic-plastic boundary, R_c, rather than the stress-field parameter, K_c. Pending an elastic-plastic analysis for the tensile case, it is worth-while to extend the results obtained in shear to the tensile case by analogy.

The elastic-plastic analysis for shear gives the radius to the elastic-plastic

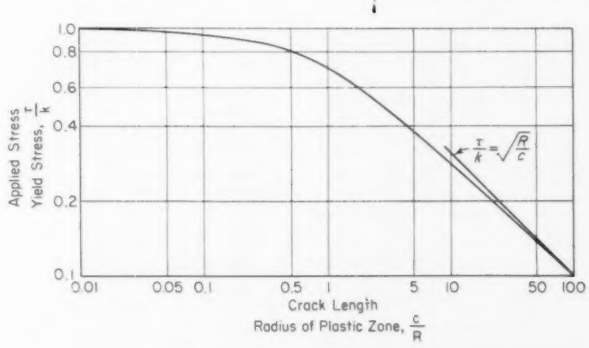

Fig. 1.—Dependence of radius of plastic zone on applied stress.

* This research was supported by the United States Air Force through the Metals and Ceramics Div., Wright Air Development Div., under contract AF 18(600)-957.

[1] "Fracture Testing of High-Strength Sheet Materials," Report of Special ASTM Committee on Fracture Testing of High-Strength Sheet Materials, ASTM BULLETIN, No. 243, Jan., pp. 29–40; No. 244, Feb., pp. 18–28, 1960.

[2] Department of Mechanical Engineering, M.I.T., Cambridge 39, Mass.

boundary, R, in terms of the following variables:[3]

a = crack length (or half crack length for an internal crack),
τ = nominal applied stress, and
K = yield strength in shear for a non-strain-hardening material.

For low stress levels, the relation approaches:

$$\frac{R}{a} = \left(\frac{\tau}{K}\right)^2 \quad \ldots\ldots\ldots\ldots (1)$$

This is twice the radius found from equating the stress obtained from an elastic analysis to the yield strength (for example, Eqs 4 and 14 of the committee report, or a similar analysis for elastic shear). This larger size is not surprising in view of the fact that the material within the plastic zone is not carrying the stress assumed in the elastic analysis, so the plastic zone must be larger. For higher stress levels, the relation between stress and size of plastic zone is most simply presented in graphical form, as shown in Fig. 1 of this discussion.

Before crack initiation, the total strain along the line directly ahead of the crack, γ^r, is given in terms of the yield strain in shear, $\gamma_y = K/G$, the radius to the elastic-plastic boundary, R, and the radius to the point in question, r:

$$\gamma^r = \gamma_y \frac{R}{r} \quad \ldots\ldots\ldots\ldots (2)$$

This differs from the elastic strain distribution in that the strain varies inversely as the first power, rather than inversely as the square root of the distance, r, from the tip of the crack.

After the crack begins to grow, the strain distribution changes, because the previous plastic strain remains while the crack grows and thus does not vary inversely as the distance to the new crack tip. An elastic analysis, on the other hand, indicates that the strain continues to vary inversely as the square root of the distance from the current tip of the crack. This difference in strain distribution leads to a different conclusion: from an elastic analysis one would expect any crack that grows to be unstable, whereas the plastic analysis leads to the observed result that cracks are initially stable, but later become unstable.

To carry out an elastic-plastic analysis for instability, one must postulate a condition for fracture. In the case of shear fracture of a nonstrain-hardening material the following criterion has been suggested:[4] *Fracture occurs when the plastic strain throughout the distance ρ directly ahead of the crack reaches a critical value $\gamma_f{}^\rho$.* The distance ρ is related to the structure of the material, being about the size within which the classical theory of plasticity no longer applies, and the strain $\gamma_f{}^\rho$ is the plastic strain at fracture in the ordinary torsion test.

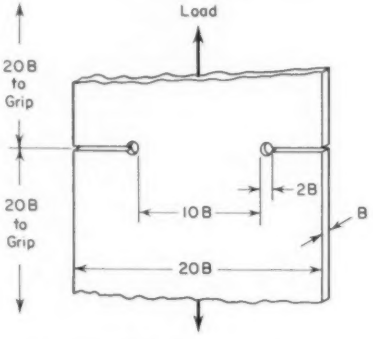

Fig. 2.—Tension specimen to produce necking normal to tension axis.

According to this fracture criterion, it follows from Eq 2 that cracking should begin when the radius to the elastic-plastic boundary is given by:

$$R_i = \frac{\rho(\gamma_f{}^\rho + \gamma_y)}{\gamma_y} \quad \ldots\ldots\ldots (3)$$

Analysis of the changes in strain during the growth of the crack[4] indicates that instability should occur when the radius to the elastic-plastic boundary is given approximately by:

$$R_c = \rho \exp \sqrt{\frac{2\gamma_f{}^\rho}{\gamma_y} - 1} \quad \ldots\ldots (4)$$

Experiments by Mackenzie[5] on crack initiation in circumferentially notched bars in torsion have confirmed Eq 3, where the structural size was the microscopically observed spacing of inhomogeneities in the strain at the bottom of the notch. The specimens were not large enough for instability to occur before they became fully plastic, so it was not possible to check Eq 4 in that case.

TABLE I.—PREDICTION OF FRACTURE INSTABILITY IN PLANE STRESS REGIME.

Material	2024 T3	7075 T6
Thickness, B, in.	0.125	0.050
Uniform strain in unnotched strip, ϵ_u	0.17	0.13
Reduction of area in constrained strip, RA, per cent	0.06	0.17
Tensile strength of unnotched strip, TS, psi	70 000	83 000
Modulus of elasticity, E, psi	10^7	10^7
$\sigma\sqrt{a/B}$ from Eqs. 5b and 6, psi	300 000	320 000
$\sigma\sqrt{a/B}$ from Irwin's data,[7] psi	270 000	290 000

Turning to cases involving tension, an analog of this equation has been found to give general agreement with experimental results on aluminum foil and, in particular, the predicted behavior of initial stability followed by an instability was observed.[4]

If the thickness of the sheet is intermediate between the structural size of the material and the critical radius to the elastic-plastic boundary for the plane stress condition, then the condition case may be considered to be one of plane stress. The following analogy between the variables in the shear analysis and those in the plane stress case has been proposed:[6]

$\tau \rightarrow \sigma$, nominal applied stress,
$K \rightarrow$ TS, tensile strength of an unnotched strip,
$\gamma_y \rightarrow \dfrac{TS}{E}$
$\gamma_f{}^\rho \rightarrow \epsilon_u - \dfrac{TS}{E}$, where ϵ_u is the uniform strain (that just before necking begins) in an unnotched strip, and
$\rho \rightarrow B(RA)$, where B is the sheet thickness and RA is the reduction of area for the specimen, shown in Fig. 2.

Hence:

$$\frac{R}{a} = f\left(\frac{\sigma}{TS}\right)^2 \text{ (from Fig. 1)} \ldots (5a)$$

or for low stress levels,

$$\frac{R}{a} = \left(\frac{\sigma}{TS}\right)^2 \quad \ldots\ldots\ldots (5b)$$

and for instability of sheet,

$$R_c = B(RA) \exp \sqrt{\frac{2\epsilon_u E}{TS - 1}} - 1 \ldots (6)$$

Test data were obtained for the above analogy and compared to the results found by Irwin[7] for large sheets. Good agreement was found, as shown in Table I. If further testing bears out these first results, it will be possible to predict fracture under plane stress conditions from relatively simple tests.

If the thickness of the sheet is large compared to the critical radius for instability under plane strain conditions, then the case may be considered to be one of plane strain. No promising analog for this case has been found, because of the difficulty of carrying out tests in which measurable or calculable amounts of strain can be produced in the presence of the triaxiality at the near tip of a crack.

It remains to show how the critical radius to the elastic-plastic boundary, R_c, is related to the K_c factor which the committee has suggested. At low stress levels, comparison of Eq 5b of this discussion and Eq 5 of the committee report gives:

[3] J. A. H. Hult and F. A. McClintock, "Elastic-Plastic Stress and Strain Distributions around Sharp Notches Under Repeated Shear," 9th International Congress for Applied Mechanics, Brussels, Vol. 8, pp. 51–58, 1957.

[4] F. A. McClintock, "Ductile Fracture Instability in Shear," *Journal Applied Mechanics*, Vol. 25, pp. 581–588, 1958.

[5] A. C. Mackenzie, "Crack Initiation in Circumferentially Notched Bars in Torsion," Master's Thesis, M.I.T., Dept. of Mechanical Eng., Sept., 1958.

[6] F. A. McClintock, Discussion of "Fracture Mode Transition for a Crack Traversing a Plate," by G. R. Irwin, *Transactions*, Am. Soc. Mechanical Eng., *J. Basic Eng.*, Vol. 82, Series D, pp. 423–425, 1960.

[7] G. R. Irwin, "Fracture Mode Transition For a Crack Traversing a Plate," *Transactions*, Am. Soc. Mechanical Eng., *J. Basic Eng.*, Vol. 82, Series D, pp. 417–423, 1960.

$$R_c = \frac{K_c^2}{\pi(TS)^2} \quad \ldots\ldots\ldots (7)$$

Thus, the critical plastic-zone radius can be determined if K_c is known, or, of course, it can be obtained directly from the data through Eq 5*a* or 5*b*.

Conclusions

1. In plastic materials at high stress levels, there is a gap between elastic stress analysis and the micromechanisms leading to fracture. The analog of the elastic-plastic analysis for cracks under shear appears useful in bridging this gap. The analysis helps to provide an insight into why cracks which are initially stable become unstable. Under conditions of plane stress, the analog suggests how the nominal stress at instability may be predicted from relatively simple tests involving only measurements of uniform strain, of tensile strength of smooth specimens, and of the specimen reduction of area, shown in Fig. 2. It is suggested that such tests be carried out in connection with any studies of crack instability and also that microscopic observations be made of the scale of inhomogeneous deformation in tests on foil or in the plane strain configuration.

2. The critical radius of the plastic zone for instability, R_c, seems as useful as K_c in correlating fracture and has the advantage of being easier to visualize. For example, the transitions in fracture appearance (Fig. 3 of the committee report) and in R_c or K_c from plane stress to plane strain (Fig. 5 of the committee report) occur at a value of R_c/B of nearly unity, whereas the value of β is about π and that of r_Y/B is about $\frac{1}{2}$.

COMMITTEE RESPONSE.—Mr. McClintock suggests that the results of K_c type fracture testing should be expressed in terms of a certain plastic zone size parameter, R_c, rather than in terms of K_c. No differences in measurement procedure are suggested. Presumably, therefore, Mr. McClintock assumes load and crack length at onset of unstable rapid crack extension may be determined as outlined in the committee's report for K_{c1} and K_{c2}. He is, however, suggesting a new framework of analysis.

The elastic-plastic model of a shear crack as worked out by McClintock and Hult[3] is of interest. Their work on this problem constitutes an exploratory attempt to solve a plasticity problem of exceptional difficulty. In relation to tensile fracturing of real solids their mathematical investigations of plastic flow near a shear crack must be regarded as exploratory for the following reasons:

1. The shear crack studies apply to tensile fracturing only by translating concepts from this study by approximate and somewhat arbitrary analogy into concepts applicable to tensile fracturing. The elastic stress fields are substantially different. Although useful to a theoretician attempting to establish approximate validity of his hypothesis, the suggested concept transfer process would require much additional study before it could be accepted as the basis for crack toughness measurements.

2. Despite the simplifying advantage of assuming a slip field in which all particle displacements are parallel to the leading edge of the crack, the working out of the crack extension problem by McClintock and Hult apparently required additional assumptions as follows:

(*a*) The material has a sharp yield point and does not strain-harden.

(*b*) The shear strain, γ_f, at a fixed small distance, ρ, from the end of the crack has a constant value.

(*c*) As the crack advances, new increments of plastic strain can be calculated without allowance for the influence of previous increments of plastic strain.

(*d*) The calculation is not affected by the dimensions of the specimen.

With reference to assumption (*b*) both γ_f and ρ must be regarded as new material property concepts. They are essential and basic to the McClintock-Hult theoretical model. Unless new measurements are added, both of these cannot be computed from the K_c experimental procedure. One must be assumed in order to calculate the other. However, McClintock does not suggest we express results in terms of either. Instead he suggests we compute the theoretical span of the plastic zone, R_c, which has no clear meaning for the complex plastic zone shape applicable to a tensile crack.

The plastic zone size correction employed in the stress analysis described in the committee report is similar to assumption (*d*) in that the correction is assumed to depend only upon K_c and the yield strength σ_{YS} and not upon specimen dimensions. However, in the report this is done only in connection with a correction factor, and the general stress analysis takes into account the specimen dimensions.

None of the above assumptions (*a*) through (*d*) is uniquely required in order to explain the growth of a crack and the relatively abrupt increase of crack velocity which furnishes an observation point for K_c measurements.

In contrast with the above circumstances the K_c analysis procedure is simple, general, and comparatively free from unrealistic assumptions. These advantages are gained by operating in a range where an elastic stress analysis has approximate validity and by an analysis procedure which neither assumes nor predicts the complex local details of inelastic deformation which comprise the crack extension process. Considering the unknown factors influencing crack extension which remain to be explored, the general descriptive approach as represented in the committee report should have value for a substantial period of time.

For the reasons discussed above the committee is not prepared to accept the specific suggestions offered by Mr. McClintock. However, the research work serving as a background for his comments is regarded by the committee as an important step toward eventual extension of our knowledge of crack extension to factors related to plastic deformation. His representation of the relationship between his theoretical work and K_c crack toughness measurements is of general assistance to the committee, and his effort in preparing and submitting a comment is appreciated.

EDITOR'S NOTE.—*The second report of this committee (whose name has been changed to "Special Committee on Fracture Testing of High-Strength Metallic Materials") will be published in the next issue of* Materials Research & Standards *under the title, "The Slow Growth and Rapid Propagation of Cracks." This report will clarify some of the practical applications of fracture mechanics concepts, particularly those dealing with the so-called slow crack growth which occurs prior to the onset of rapid propagation, and at lower stresses.*

Effects of Nuclear Radiation on Rubber

By J. W. BORN

When a new technology develops, its pioneer scientists and engineers inherit the existing materials of construction. Previously satisfactory materials are often marginal or even unacceptable for the new requirements. In any case they must be tested and proved anew. Such is now the case for rubbers and plastics in intense fields of nuclear radiation. This discussion provides insight into basic effects of such radiation. It further shows how radiation effects can be used to advantage (as beneficial effects), defines radiation damage to rubber in terms of stress-strain and dynamic mechanical properties, and indicates how to partially inhibit such detrimental effects in rubber polymers and products.

ALTHOUGH the term nuclear radiation properly includes various types of radiation, including alpha, beta, gamma, neutron, and many more, this discussion will apply essentially to gamma rays and fast neutrons. The latter two forms of nuclear energy are highly penetrating ionizing radiations which accordingly distribute energy quite uniformly throughout a polymeric material. Therefore, they induce progressive chemical and physical changes in rubbers and plastics which are proportional in magnitude to the total amount of energy transferred to the polymer. As in the case of other forms of energy which affect high polymers, the associated environmental conditions influence the net changes. The amount of energy deposited is measured in rads in the case of gamma and electron radiation and in thermal, epithermal, and fast neutrons per square centimeter for neutron radiation. The rad is equivalent to 100 ergs of absorbed energy per gram of the material.

Nuclear irradiation of organic high polymers causes two primary basic effects: ionization and excitation, as represented schematically in Fig. 1. The wavy arrow indicates a radiation-induced reaction. Ionization results from ejection of an electron from a molecule. Excitation can arise either from direct energizing of the neutral molecule or from the combination of a positively charged polymer molecule with an electron. In either case the interaction produces an excited molecule. In the usual energy ranges only neutrons cause transmutations of atoms which may form radionuclides in the third primary process. However, this discussion will neglect transmutation because in general its results are insignificant compared with the changes induced by the first two processes.

A variety of secondary reactions ensue from the primary processes, namely, crosslinking; chain or bond scission; molecular rearrangement, both saturation and unsaturation; and formation of by-products (Fig. 2). Several mechanisms have been proposed for radiation-induced crosslinking, including free-radical transfer or combination, hydrogen abstraction, and ion-molecule reaction. Briefly explained, these concepts are as follows. In free-radical crosslinking two adjacent free radicals on separate polymer molecular segments are considered to unite to form an electron pair or covalent bond crosslink. The two free radicals may be adjacent when first formed or, it is postulated, may become adjacent as a result of the migration of one or both radicals along the macromolecular chain or chains. It is also possible that a free radical may transfer from one polymer chain to another. Hydrogen abstraction signifies that an

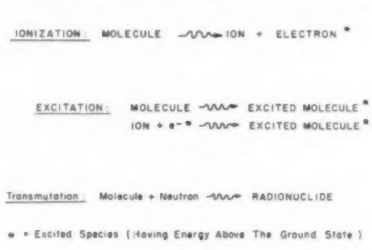

Fig. 1.—Primary radiation-induced processes.

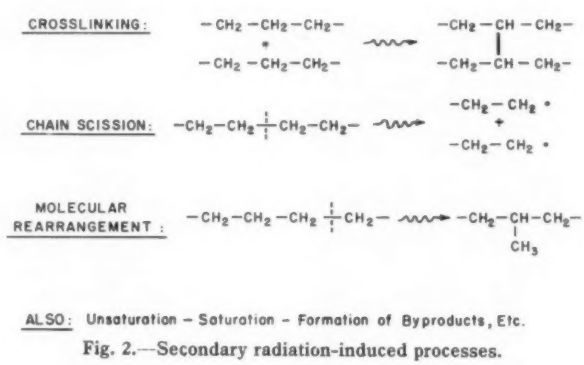

Fig. 2.—Secondary radiation-induced processes.

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TABLE I.—STRUCTURE OF POLYISOPRENES.

	Per Cent 1,2-	Per Cent 3,4-	Per Cent 1,4-(Addition)
Radical mechanism (peroxide)	5.3	5.2	89.5
Ionic mechanism (Alfin)	4.7	23.0	72.3
(Sodium)	6.6	55.0	38.4
(BF_3)	3.7	6.6	89.7
Gamma rays (10^6 rads)	8.0	8.0	84.0

excited hydrogen atom on one polymer molecule abstracts a hydrogen atom from a nearby polymer molecule. The result is the formation of a chemical crosslink with the evolution of a hydrogen molecule. In the case of the ion molecule it is postulated that an ionized polymer molecule in a highly energetic state approaches another polymer molecule, transfers its ionic charge to the latter polymer, forms a crosslink to this second chain, and produces a new ion—perhaps a proton. There are schools of thought supporting each of the three postulated mechanisms, and, indeed, it is likely that more than one can apply, depending upon the polymer system and environment. Unsaturation may thus be considered a special type of hydrogen abstraction in which the adjacent atoms are on the same polymer chain. When they are removed, an ethylenic double bond results.

Chain scission results from breaking a bond in a main chain of a polymer rather than in a side group. When radiation highly energizes a polymer molecule, any steric strain or stretching or bending force will promote permanent chain scission. Temporary chain scissions appear to be from 10 to 100 times as numerous as permanent ones in unstressed polymers (**1**).[1] That is, the great majority of chains broken by irradiation reunite or "heal" before the ends can move apart. An alternate possible consequence of chain scission is endlinking, which is the trifunctional combination of a free radical at one of the ruptured molecular ends with a free radical along the length of a polymer chain.

Other molecular rearrangements also occur to a relatively small yet significant extent during irradiation. They may comprise numerous types. Two examples are (1) branching, as represented in Fig. 2, and (2) the opening of the benzene rings of polystyrene after very large radiation doses.

As an auxiliary point, fragments of low molecular weight can break away and become stabilized. For example, polyhydrocarbons yield hydrogen, methane, ethane, and perhaps propane and even larger molecules during irradiation. These constitute by-products, which may prove undesirable in some cases.

The distinctions between beneficial and detrimental effects of radiation are differences in kind in some cases but in degree in all cases. To clarify the matter, the two categories will be reviewed in detail.

Beneficial Effects of Radiation on Rubbers

Four beneficial effects of nuclear radiation have been selected for discussion. Other applications exist but are of less consequence here. The four are polymerization, graft copolymerization, vulcanization, and post-vulcanization.

Polymerization

High-energy irradiation generally polymerizes vinyl-type monomers but does not cause condensation-type polymerizations (**2**). For example, isoprene and isobutylene can be polymerized by irradiation (**3**, **4**). Radiation polymerizations proceed mainly by free-radical mechanisms (**5**), at least at room temperature and above. However, ionic polymerization can occur. As illustrated in Table I, polyisoprene produced by gamma irradiation at either room temperature or −40 C has a structure which indicates predominantly free-radical polymerization accompanied by some ionic reaction (**3**).

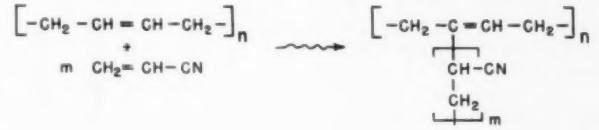
On the other hand, liquid isobutylene at −78 C undergoes completely ionic polymerization. Although free radicals are formed, no free-radical polymerization is observed (**4**). The reaction probably proceeds by a cationic mechanism.

Two distinctive aspects of radiation-induced polymerization are (1) the production of ions and free radicals is independent of temperature, and (2) no catalyst fragments or polymerization agents remain at the conclusion. In special cases these may be desirable advantages. However, in general, chemical induction is equally or more effective, cheaper, and technically simpler today than radiation induction.

Graft Polymerization

One of the most promising radiation applications to rubber at this stage of the art is graft copolymerization. This process involves the radiation-induced polymerization of a selected monomer onto an existing polymer. It may be accomplished either by first irradiating the dry polymer, preferably in a vacuum or in an inert gas, and subsequently immersing it in the monomer, or by irradiating the polymer while immersed in the monomer. In either case free-radical sites are produced on the polymer molecules, and monomer molecules form new polymer chains attached to the old. Such grafting produces an armor of sorts about the original polymer molecules. The resulting copolymer has some of the properties of each homopolymer. Consequently, many kinds of interesting and practical opportunities arise. Using a starting polymer having certain essential properties such as good stress-strain properties or heat resistance, one can then armor the base polymer with another polymer to meet additional environmental or service requirements, as summarized in Fig. 3. Among these may be improved chemical and solvent resistance, adhesion or tack, compatibility with other rubbers, stress-strain properties, abrasion resistance, electrical properties, impermeability to gases, or dyeability or printability.

For example, grafting acrylonitrile



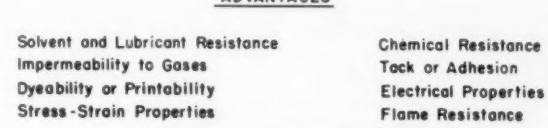


Fig. 3.—Radiation-induced graft copolymerization.

onto vulcanized dimethylsiloxane rubber markedly increases its resistance to hydrocarbon fluids. A radiation dose of 0.5 megarads transforms the elastic vulcanizate, immersed in acrylonitrile, into a viscoelastic graft copolymer containing 34 per cent grafted acrylonitrile (**6**).

Four factors can influence the efficiency of grafting: (1) temperature, as it defines the reaction rates and the solubility or degree of swell of the polymer in the monomer; (2) radiation dose rate; (3) diffusion rate of monomer

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

into the polymer, which is dependent upon thickness; and (4) variation of the solubility of monomer in polymer with the degree of grafting, which changes the radiation sensitivity of the derived structure (**6**).

Vulcanization

Crosslinking is one of the principal and most important radiation effects in rubber. In the case of uncured or undercured rubber polymers or compounds, radiation-induced crosslinking results in vulcanization. Nearly all elastomers undergo such vulcanization. The two common exceptions are polyisobutylene, or butyl rubber, and the organic polysulfide elastomers, which undergo predominant chain scission during irradiation.

The gamma radiation exposure doses required to produce "optimum" cures for ten elastomers of general interest are shown in Fig. 4 (**7**). A typical reinforced rubber compound was used in each case. The doses ranged from 10 to 40 megarads. That dose which gave the same apparent molecular weight between crosslinks (M_c) as the "optimum" chemical cure was chosen for comparison in each case. The elastomers depicted by black bars in Fig. 4 contain fluorine and must be irradiated in a vacuum or in an inert atmosphere in order to obtain satisfactory physical properties.

Figure 5 compares four radiation cures with ten chemical cures, involving natural rubber (NR), chloroprene rubber (CR), styrene-butadiene rubber (SBR), and nitrile-butadiene rubber (NBR). The separate chemical curing agents included sulfur, tetramethylthiuram disulfide (TMTD), and dicumyl peroxide for NR, NBR, and SBR, but only magnesium oxide for CR. For these four elastomers, radiation cures produced lower stress-strain values, better abrasion resistance, and higher hysteresis or heat rise during cyclic flexing. In order of decreasing stress-strain values obtained by radiation vulcanization, these elastomers rank NBR > NR > SBR > CR. In the case of the fluorinated polymers, radiation-induced crosslinking gave higher stress-strain values than did the chemical curing systems.

Figure 6(*a*) shows the decrease in tensile strength with heat aging for a peroxide cure versus radiation cures of natural rubber. The radiation cure without the antioxidant phenyl-β-naphthylamine (PBNA) present is inferior in age resistance to the peroxide cure for natural rubber with PBNA present, because of accelerated oxidation. However, when PBNA is present in both cases, the radiation cure exhibits the better age resistance. Similarly, as shown in Fig. 6(*b*), with PBNA present the chemical cure is nearly equivalent up to 200 F in retention of ultimate elongation but becomes increasingly inferior thereafter.

In order to make radiation vulcanization economical, the radiation dose necessary to produce the optimum degree of crosslinking must be reduced by a factor of 10. Both heat and certain chemicals can accelerate radiation vulcanization, but the increase in rate is insufficient so far (**8**). On the other hand, radiation vulcanization has the following advantages: cold vulcanization of molded or extruded goods can be accomplished, post-curing associated with reactions of residual curing agents at elevated temperatures does not occur, uniform cures of thick items result which are difficult to obtain by conventional means, and elastomers whose chemical cure is difficult or presently impossible may vulcanize during irradiation.

Post-Vulcanization

Post-vulcanization signifies additional

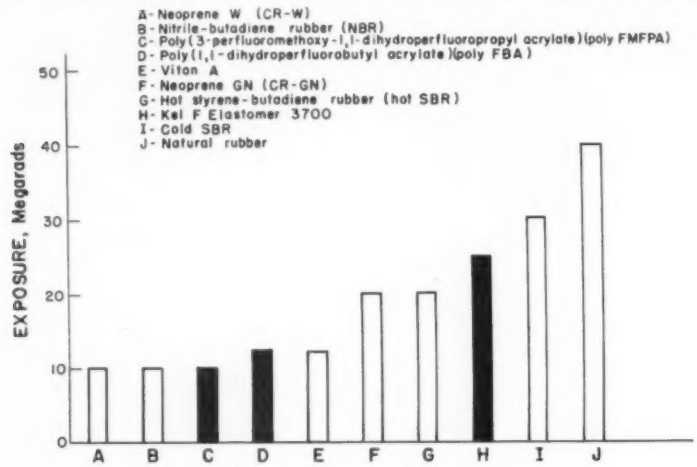


Fig. 4.—Radiation exposure to obtain optimum cure.

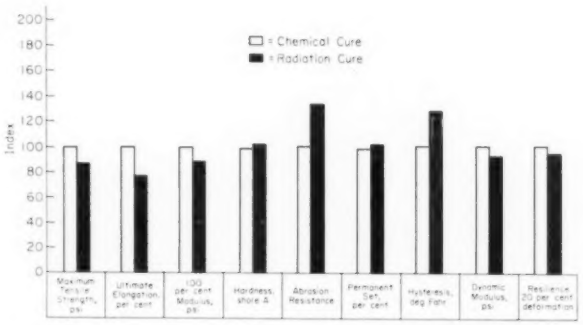


Fig. 5.—Comparison of radiation and chemical cures at equivalent molecular weight between crosslinks.

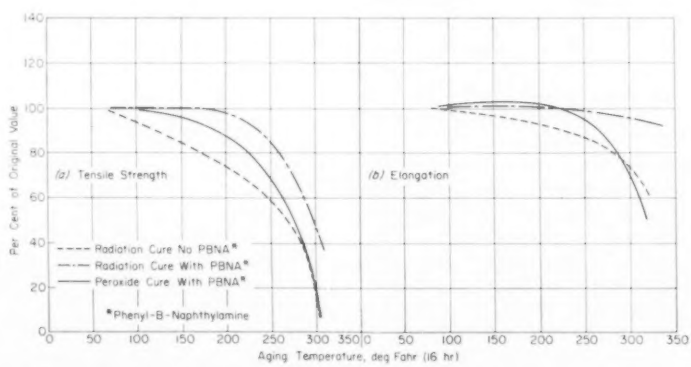


Fig. 6.—Per cent of initial tensile strength (*a*), and initial ultimate elongation (*b*), versus aging temperature (NR with 50 phr of EPC black).

crosslinking subsequent to the principal vulcanization of the rubber. Usually such added cure is purposely localized at the surface or some other restricted part of the rubber product to improve service performance. Examples might well be the surface post-cure of SBR tire tread to improve abrasion resistance without deterioration of the tire cord, or of golf ball covers to improve resistance to cutting and scuffing and to increase rebound without harming the gum rubber thread in the core. Accelerated electron radiation is generally used for applications such as these because of the limited, controllable penetration of the radiation into the rubber product. Post-vulcanization also can be used to give a different shape to a rubber product.

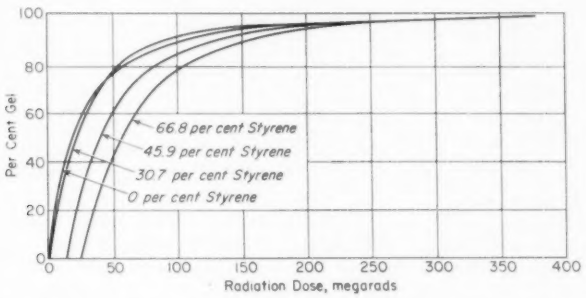


Fig. 7.—Radiation-induced crosslinking in styrene-butadiene copolymers.

Detrimental Effects of Radiation on Rubber

The interest in detrimental effects of radiation on rubber materials is defensive in nature. Since radiation constitutes a new environmental aging factor for rubber in nuclear applications, the rubber scientists must determine the nature and extent of radiation damage under given circumstances. Also, they must seek ways of increasing radiation resistance. Thus, they concern themselves with defining, understanding, and preventing radiation damage.

Crosslinking Versus Chain Scission

Irradiation of rubbers simultaneously produces both chain scission and crosslinking in most, if not all, cases. This competition results in a net effect in which one or the other molecular structural change usually predominates, tending to produce a dynamic equilibrium state, as shown in Fig. 7. The per cent gel, a measure of the degree of crosslinking of an elastomer, apparently approaches an asymptotic value of less than 100 per cent with increasing radiation dose.

Even if the number of bonds formed exactly equalled the number broken during irradiation, it is probable that the new bonds would not be equivalent to the old. Thus, if the rubber is in an optimum state of cure when irradiation begins, any radiation-induced change in molecular structure is quite certain to be detrimental to the general physical properties. Let us assume hereafter that we are discussing optimum-cured rubbers.

Crosslinking

Most elastomers predominantly undergo crosslinking as opposed to chain scission. The net tangible results are increased specific gravity, hardness, modulus, and degree of crosslinking; decreased tensile strength and ultimate elongation (Fig. 8(*a*)); and eventual attainment of a rigid, glass-like state.

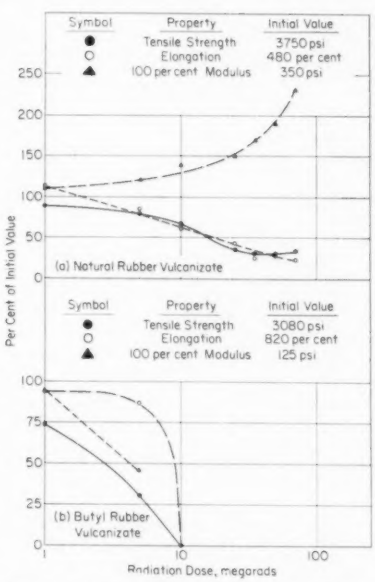


Fig. 8.—Radiation effects on carbon-black-reinforced natural rubber vulcanizates.

Chain Scission

In comparison, Fig. 8(*b*) represents the typical changes that occur in the stress-strain properties of elastomers undergoing net chain scission. Butyl rubber and polysulfide rubbers are among the few elastomers in this category. They display decreases in tensile strength, modulus, ultimate elongation, hardness, specific gravity, and molecular weight. Eventually, such elastomers attain a semifluid or fluid state.

Rubber under stress is subject to two types of severe progressive failure in conventional environments, namely, stress relaxation during extension and permanent set during compression. Both of these processes result from chain scission and are accelerated by irradiating the stressed rubber. In fact, these may well prove to be among the most critical forms of radiation damage in service. Crosslinking may also play a role in these processes, particularly in permanent set.

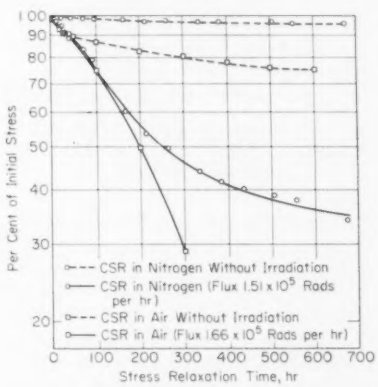


Fig. 9.—Radiation-induced continuous stress relaxation of gum natural rubber vulcanizate.

TABLE II.—EFFECT OF ANTIRADS ON CHAIN SCISSION AND CROSSLINKING YIELDS.

Radiation Damage Inhibitor (Antirad) (5 phr in Carbon-Black-Reinforced NR)	*G* (Events per 100 ev)			
	Scissions		Crosslinks	
	Nitrogen	Air	Vacuum	Air
None (1 phr phenyl-2-naphthylamine)	2.7	13.	1.9	0.29
N-Phenyl-*N'o*-tolylethylenediamine	1.8	4.3	1.1	0.28
N-Cyclohexyl-*N'*-phenyl-*p*-phenylenediamine	1.2	1.4	1.3	0.33
6-Phenyl-2,2,4-trimethyl-1,2-dihydroquinoline	1.9	4.2	0.83	0.19
N-*N'*-Dioctyl-*p*-phenylenediamine	1.5	5.0	0.87	0.12
2-Naphthylamine	1.6	5.6	0.87	0.30
1,4-Naphthoquinone	2.0	5.6	1.1	0.48
Phenylhydroquinone	2.2	5.4	1.1	0.46
2-Naphthol	1.3	4.1	1.1	0.24
N,*N'*-Diphenyl-*p*-phenylenediamine (35 per cent plus phenyl-1-naphthylamine (65 per cent)	1.4	3.7	0.97	0.27
N,*N'*-Dicyclohexyl-*p*-phenylenediamine	1.5	3.0	...	...
p-Quinone	2.8	7.8	...	...

Oxidation and Ozonization

It is important to consider two other detrimental radiation effects in gaining a proper understanding of general radiation damage. They are radiation-induced oxidation and ozonization, or ozone attack, of rubber. These are old enemies which are intensified by irradiation. Figure 9 compares the rates of

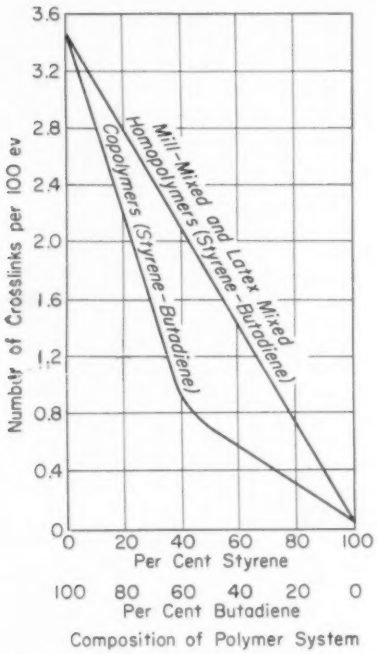


Fig. 10.—Radiation resistance of styrene-butadiene copolymer and mixed homopolymer systems.

radiation-induced continuous stress relaxation of natural rubber gum vulcanizate in air and in oxygen-free nitrogen. The comparison suggests that as much as half the chain scission under stress is due to radiation-accelerated attack by oxygen and ozone.

The latter effects indicate the importance of both antioxidants and antiozonants in rubber vulcanizates for radiation service. It is also apparent that rubber in a vacuum, in an inert gas, or submerged in an inert fluid will undergo less deterioration than the same rubber irradiated in air to the same radiation dose. Also, the permeability of the rubber to oxygen affects gross radiation resistance in air. The oxygen initially dissolved in the rubber quickly reacts during irradiation. Any further oxygen or ozone attack therefore depends upon how fast oxygen can diffuse into the material.

Inhibitors of Nonoxidative Radiation Damage

Since an appreciable part of radiation damage to rubber is apparently nonoxidative, it is important to consider means of inhibiting radiation effects besides using antioxidants and antiozonants. Chemical additives have been discovered for rubber which have specific abilities to inhibit either crosslinking or chain scission during irradiation. Furthermore, as listed in Table II for natural rubber, these inhibitors can be effective even when the rubber is evacuated and kept in a high vacuum (or completely flushed and kept in oxygen-free nitrogen) (1,9). For example, *N*-cyclohexyl-*N'*-phenyl-*p*-phenylenediamine reduces the rate of chain scission of the normally protected control stock to 45 per cent of the control value in nitrogen and 9 per cent in air. Similarly, the addition of 5 parts per hundred rubber (phr) of *N,N'*-dioctyl-*p*-phenylenediamine reduces the rate of crosslinking of the control stock to 46 per

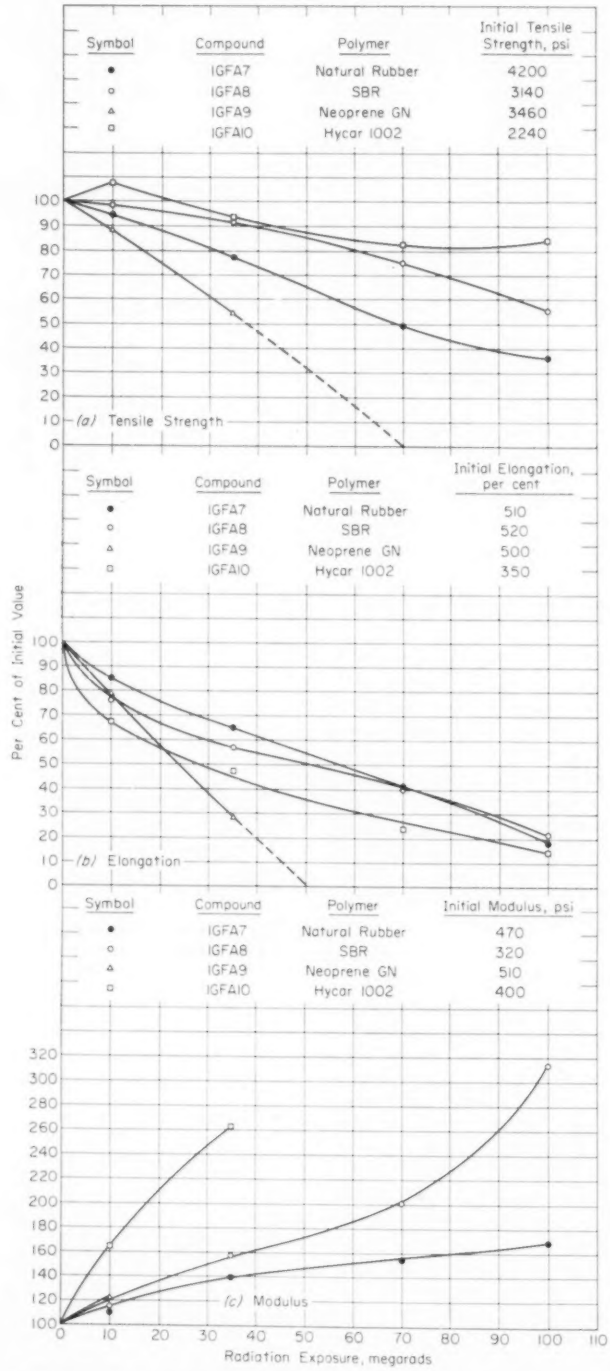


Fig. 11—Radiation effects on tensile strength (*a*), ultimate elongation (*b*), and 100 per cent modulus (*c*)

cent of the control value in vacuum and 42 per cent in air. Also, the order of effectiveness of the inhibitors as antirads does not appear to correspond with that as antioxidants. They therefore appear to constitute a distinct group of radiation protective agents.

An alternate approach to mixing the inhibitor into the rubber compound, from which it may later be removed in various ways (leaching or melting and exuding), is to incorporate the protective group right into the polymer molecular structure itself. In this way the radiation resistance becomes inherent in the elastomer. The B. F. Goodrich Co. is engaged in just such an effort now, under a contract with the Air Research and Development Command of the U. S. Air Force. The potential protective groups, chosen on the basis of the company's prior antirad research, are being incorporated into monomer molecules, both as side groups and in the main chain. The polymers synthesized from these "custom-made" monomers are now being evaluated for inherent radiation stability (**10**).

The protective groups in such polymer molecules are mainly aromatic structures, situated at various distances from reactive sites of the main chain. These groups appear to protect by absorbing the radiation energy selectively and dissipating it through resonance without critically changing the polymer structure. Figure 10 illustrates this point for the styrene-butadiene copolymer system. The intimate physical mixture of polystyrene with polybutadiene results simply in dilution of the polybutadiene and of the damage to the latter homopolymer, as indicated by the linear relationship between radiation dose and per cent gel, or degree of crosslinking. In comparison, the styrene repeating unit in the copolymer series with butadiene specifically inhibits crosslinking, as evidenced by the departure of the curve in Fig. 10 from a straight line. In addition to resonating structures, highly branched electropositive substituent groups such as tertiary-butyl or neopentyl appear to inhibit radiation effects.

Typical Examples of Radiation Damage

After these brief discussions of a wide variety of beneficial and detrimental radiation effects, let us examine the effect of large radiation exposure doses on physical properties of representative vulcanized rubber compounds (**11**). Carbon-black-reinforced vulcanizates of natural rubber (NR), styrene-butadiene rubber (SBR), neoprene GN (CR), and nitrile-butadiene rubber (NBR) are included in Figs. 11 through 13. Figure 11(*a*) shows the change in tensile strength with irradiation. Note the initial added vulcanization of nitrile rubber (NBR), indicating slight undercure. The nitrile rubber retained its tensile strength best, followed by styrene-butadiene rubber, natural rubber, and chloroprene rubber in order of decreasing resistance to radiation damage.

Consider the rate of decrease in ultimate elongation with irradiation (Fig. 11(*b*)). Natural rubber and styrene-butadiene rubber are most resistant, followed by nitrile-butadiene and chloroprene rubbers, in that order. Note that, unlike the other three, chloroprene rubber suffers complete failure in both tensile strength and ultimate elongation far short of the 100-megarad total exposure. (The broken-line portion of the curve represents an extrapolation.) Also, one should observe that the deterioration rate is much greater early in the radiation exposure for ultimate elongation than for tensile strength for all rubbers except neoprene. Thereafter, the rates are quite similar.

Figure 11(*c*) follows the changes in 100 per cent modulus (that is, rubber modulus at 100 per cent elongation) with radiation exposure. Here, natural rubber shows the best retention of the initial modulus, followed by SBR and NBR in order. Again, CR failed early in the exposure period.

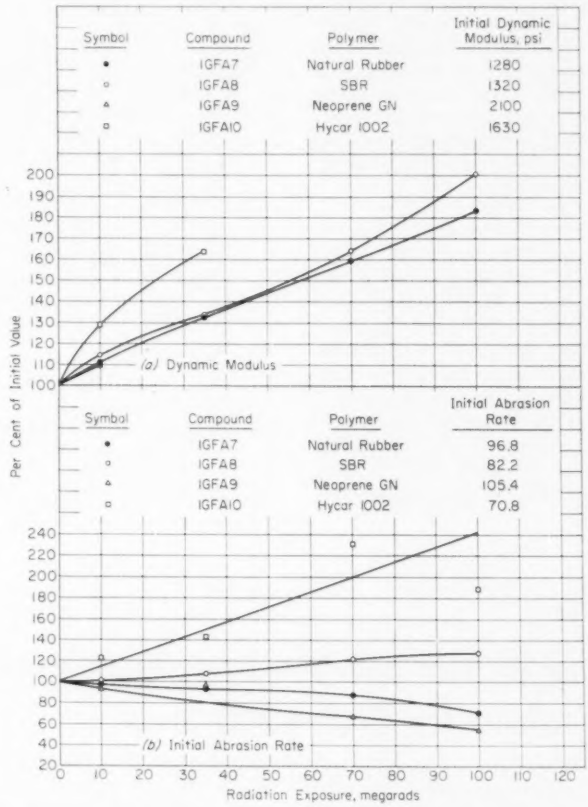


Fig. 12.—Radiation effects on dynamic modulus (*a*), an initial abrasion rate (*b*).

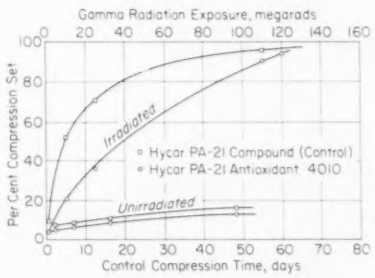


Fig. 13.—Changes in compression set during irradiation.

The changes in the dynamic modulus, shown in Fig. 12(*a*), closely parallel those in the 100 per cent modulus (Fig. 11(*c*)). The radiation-induced effect on abrasion rate (Fig. 12(*b*)) ranks the four rubber compounds in the same order of resistance, except that chloroprene rubber compares fairly well with natural rubber. However, note that if one were selecting a rubber for best absolute abrasion rate after the 100-megarad exposure, he would probably select the SBR rubber with its 30 per cent increase in abrasion resistance rather than the natural rubber with its 30 per cent decrease.

Finally, Fig. 13 illustrates net changes in per cent compression set *during* irradiation as a function of radiation ex-

posure dose for nitrile-butadiene rubber and for acrylate-butadiene rubber. The curves have been corrected for conventional compression set during the testing period and so represent the net permanent set due to irradiation alone *during* the exposure. The rate of radiation-induced compression set is marked for the rubbers with normal age resisters present. However, when certain antirads are added to the rubber compounds, radiation resistance increases considerably, as shown by the lower one of the pair of curves representing the irradiated samples. The nitrile-butadiene and acrylate-butadiene rubber compounds have shown the greatest amount of protection by antirads of all the rubbers tested so far.

Conclusions

The foregoing discussion was meant to provide some understanding of the beneficial and the detrimental effects of nuclear radiation on rubbers. It would be misleading and incorrect to suggest that the problems associated with these effects are solved. Instead, it is correct to say that more and more concerted and educated effort is being channeled toward their solution. This is true whether the problem is to use the good effects of radiation constructively and economically or to inhibit radiation-induced bad effects for the present by the physical addition of inhibitors or eventually by the synthesis and compounding of elastomers having inherent radiation stability. In either case, the radiation chemist is faced with new challenges from his technological environment.

References

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(3) W. J. Burlant and D. H. Green, "Some Gamma-Ray Initiated Polymerizations," *Journal of Polymer Science*, Vol. 31, pp. 227–230, Aug., 1958.

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(9) R. G. Bauman and J. W. Born, "The Mechanism of Radiation Damage to Elastomers. I. Chain Scission and Antirad Action," *Journal of Applied Polymer Science*, Vol. I, pp. 351–355, 1959.

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(11) J. W. Born, *et al.*, "A Study of the Effects of Nuclear Radiations on Elastomeric Compounds and Compounding Materials," *WADC Technical Report* **55-58**, Part III, The B. F. Goodrich Co. Research Center, Dec., 1956.

Discussion of Paper on Low-Temperature Tensile-Hardness Correlations for SAE 4340 Steel[1]

J. W. Sands.[2] Shortly before the appearance of the paper by Messrs Nunes and Larson, the Mond Nickel Co. Ltd., of London, disclosed the results of an extensive low-temperature investigation in a book entitled "The Mechanical Properties of Nickel Alloy Steels at Sub-Zero Temperatures." A comparison of their findings with those of the present authors is most revealing.

The Mond work on the low-temperature tensile properties of low-alloy steels covered a series of 19 nickel, nickel-chromium, nickel-molybdenum, and nickel-chromium-molybdenum compositions, comprising direct hardening, carburizing, and plate steels. Conditions of heat treatment included oil-quenched and tempered, normalized, and normalized and tempered. They were tested at temperatures from room temperature down to −196 C. Tests over this temperature range were made on 53 different combinations of composition and heat treatment.

The compositional range of the alloying elements and the ranges of tempering temperature and room-temperature strength and hardness which were covered are indicated in Table I. The oil-quenched specimens were heat treated as ⅝-in. rounds. The normalized and normalized-and-tempered steels were in the form of ½-in., 1¼-in., and 2-in. plate.

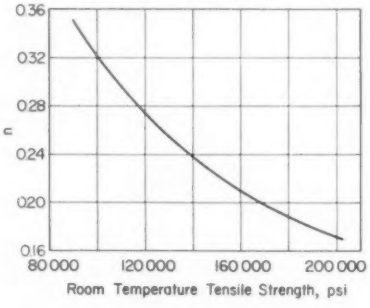

Fig. 1.—Values for n in Mond equation.

Examination of the large amount of data thus obtained indicated that regardless of heat treatment an empirical relationship exists between the tensile strength and the absolute temperature. The relation can be represented by the equation:

$$UTS_T = cT^{-n} \quad \ldots\ldots\ldots (1)$$

where c and n are constants which depend on the value of the tensile strength at room temperature.

TABLE I.—RANGE OF THE STEELS USED IN THE MOND WORK. NINETEEN STEELS; GRAIN SIZE 7 to 9.

	Alloying Element, per cent						Tempering Temperature, deg Fahr	Tensile Strength, psi	Diamond Pyramid Hardness
	Carbon	Manganese	Nickel	Chromium	Molybdenum	Vanadium			
Minimum	0.09	0.33	1.63	0.13	Nil	Nil	400	72 500	150
Maximum	0.42	0.57	4.87	1.37	1.10	0.23	1220	270 000	566

[1] J. Nunes and R. Larson, "Low-Temperature Tensile-Hardness Correlations for SAE 4340 Steel," ASTM Bulletin, No. 249, Oct., 1960, p. 25.

[2] Coordinator of Technical Publications, International Nickel Co., Inc.

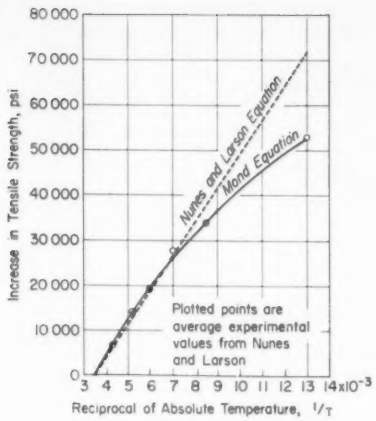

Fig. 2.—Calculated and experimental increase in strength versus reciprocal of absolute temperature.

This equation may be rewritten:

$$\log UTS_T - \log UTS_{RT} = n(\log RT - \log T) \quad \ldots\ldots (2)$$

The value of n for a given room-temperature tensile strength may be obtained from Fig. 1.

When calculations are carried out on the basis of Eq 2 it develops that at a given temperature the increase in tensile strength over the room-temperature strength is a constant, regardless of the value of the room-temperature strength or how it was obtained. In this particular the findings agree with those of the present authors. Table II shows, for the testing temperatures employed by Nunes and Larson, the increases in strength as calculated by their equation and by the Mond equation, together with the average increases actually obtained by Nunes and Larson.

The Nunes and Larson equation states that not only is the difference in tensile strength ($UTS_T - UTS_{RT}$) a constant at a given temperature, T, but further that this constant is directly proportional to $1/T$. On this point the two equations do not agree. In Fig. 2 the calculated increase in strength as determined by the two equations is plotted against the reciprocal of the absolute temperature. The Nunes and Larson equation, of course, yields a straight line. The Mond equation, on the other hand, yields a curve, indicating a decrease in the rate of strength increase with increase in the reciprocal of the temperature. It would seem that this must be the case, for if the Nunes and Larson curve were extrapolated to, say, the temperature of liquid hydrogen

TABLE II.—CALCULATED AND EXPERIMENTAL INCREASE IN STRENGTH AT LOW TEMPERATURES.

Temperature			Increase in Ultimate Strength, psi		
			Calculated		
deg Cent	deg Kelvin	$1/T$	Nunes and Larson Equation[a]	Mond Equation[b]	Observed Average, Nunes and Larson
20	293	3.42×10^{-3}	...	...	...
−40	233	4.29	6 540	7 400	6 630
−80	193	5.18	13 200	14 200	14 200
−105	168	5.96	19 100	19 700	19 200
−130	143	7.00	26 900	26 000	27 900
−155	118	8.48	38 000	33 800	34 100
−196	77	13.00	72 000	52 500	52 900

[a] $UTS_T - UTS_{RT} = 7{,}520{,}000\,(1/T - 0.00342)$.
[b] $\log UTS_T - \log UTS_{RT} = n(\log 293 - \log T)$.

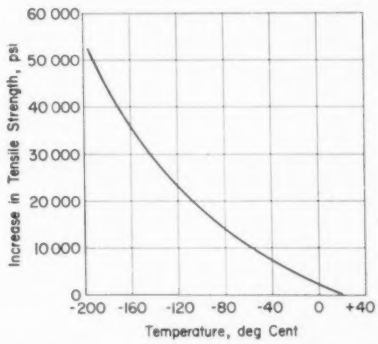

Fig. 3.—Increase in tensile strength at low temperatures (Mond).

(−253 C), the indicated strength increase would be on the order of 350,000 psi. Actual tests on 4340 steel have given values of 62,000 to 80,000 psi.[3,4] The averages of the Nunes and Larson experimental data, as indicated by the plotted points in Fig. 2, fit the Mond curve very nicely.

All this boils down to the apparent fact that a good approximation of the increase in tensile strength over the room-temperature value to be expected at temperatures down to −196 C can be read off the simple curve of Fig. 3 without recourse to complicated equations, absolute temperatures, or log tables.

In the matter of the Vickers hardness there is a very wide divergence between the data of Mond and those of Nunes and Larson. The straight-line curve of Fig. 4, based on the Nunes and Larson equation, fits their data well. Their experimental data show an average increase in Vickers hardness of 158 at −196 C, and this is the value indicated by their equation. The curve for the calculated slope in Fig. 3 of their paper indicates that each unit change in Vickers hardness number is equivalent to 460 psi. On this basis the Vickers hardness number increase of 158 corresponds to a strength increase of about 72,000 psi, which is the value projected by their tensile strength equation, but which neither they nor Mond achieved.

On the other hand, if the conversion factor holds at low temperatures, Mond should have developed a Vickers increase at −196 C of 114. Instead, the average on 26 combinations of composition and heat treatment was 68. In the Mond tests the room-temperature hardnesses corresponded well to the factor of 460, but as the temperature was decreased the hardness did not increase as rapidly as the strength. In the Nunes and Larson tests the reverse seems to be true. These differences would seem to be unreconcilable on any rational basis. The only apparent difference in procedure was the use of an extended diamond indenter by Mond.

If the Mond data are sound, they indicate that the commonly accepted re-

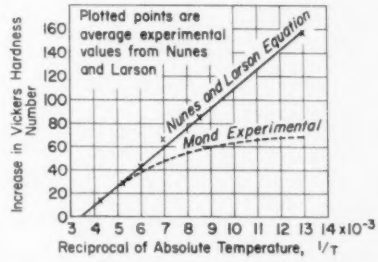

Fig. 4.—Calculated and experimental increase in Vickers hardness at low temperatures.

lationship between Vickers hardness and tensile strength is valid only at room temperatures.

J. NUNES (*author*).—We wish to thank Mr. Sands for his most interesting comments. We find ourselves, however, in disagreement with some of his conclusions.

It is generally conceded in the area of empirical correlations that first approximations (where one variable varies linearly with respect to another) are likely to be more accurate than approximations using nonlinear functions. The Mond equation, which is a complex function involving an exponential, would be no more accurate than the authors' when the proper limits are established for their constant of proportionality. These limits would be inherent in any type of approximation involving tensile strength with temperature because of compositional effects and deformation

[3] R. L. McGhee, J. E. Campbell, R. L. Carlson, and G. K. Manning, "The Mechanical Properties of Certain Aircraft Structural Metals at Very Low Temperatures," *Technical Report 58-386*, Wright Air Development Center (June, 1958).

[4] E. T. Wessel, "Some Exploratory Observations of the Tensile Properties of Metals at Very Low Temperatures," *Transactions*, Am. Soc. Metals, Vol. 49 (1957), p. 149.

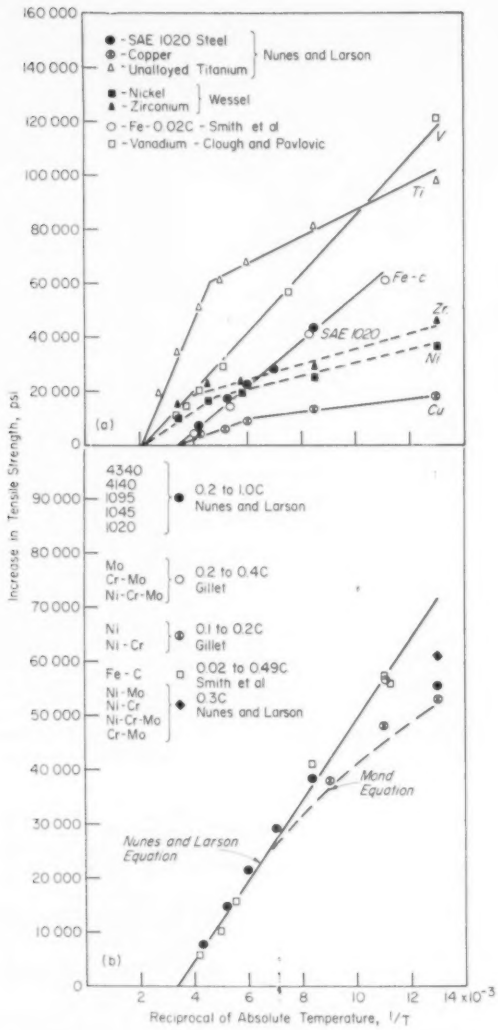

Fig. 5.—Increase in tensile strength versus reciprocal of absolute temperature.

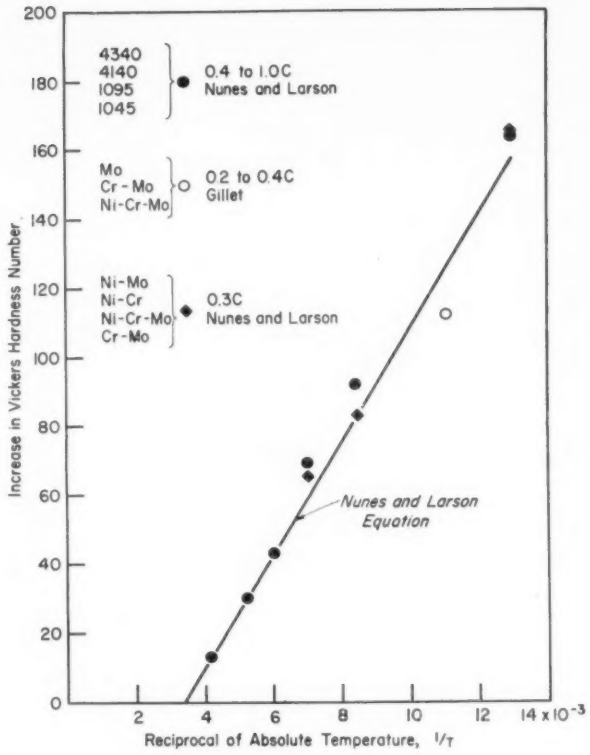

Fig. 6.—Increase in hardness for various steels versus reciprocal of absolute temperature.

changes that would influence the increase in tensile strength with decreasing temperature. Illustrated in Fig. 5(*a*) are data showing this increase in tensile strength versus the reciprocal absolute temperature for SAE 1020 steel, copper, and titanium tested by the authors, nickel and zirconium from Wessel,[4] iron-0.02 percent carbon from Smith, *et al*,[5] and vanadium from Clough and Pavlovic.[6] From the large variation in slopes shown here, it can be seen that the base element and variations in composition influence the amount of increase in tensile strength with decreasing temperature. Also, it would not seem too unreasonable to associate the breaks in the curves for the hexagonal-close-packed and face-centered-cubic metals with a change in deformation mechanism.

In Fig. 5(*b*), which is similar to Mr. Sands' Fig. 2, the increase in tensile strength over room-temperature strength is plotted versus the reciprocal of absolute temperature. The average strengths are shown for 15 different carbon and low-alloy steels which the authors have tested, 13 alloys from Gillet,[7] and eight iron-carbon alloys from Smith, *et al*. These alloy steels were primarily nickel-chromium-molybdenum chromium-molybdenum, nickel-molybdenum, nickel-chromium and molybdenum types with 0.2 to 0.4 per cent carbon in the annealed and heat-treated condition. The carbon content of the iron-carbon alloys varied from 0.02 to 0.49 per cent in a relatively high-purity iron. The four nickel and nickel-chromium steels from Gillet contained 0.1 to 0.2 per cent carbon with 3.0 to 5.0 per cent nickel. It can be seen that the average data points follow the authors' linear correlation reasonably well to −184 C ($1/T = 11.2 \times 10^{-3}$). The authors attribute the lower values observed at −196 C ($1/T = 13.0 \times 10^{-3}$) to nonadiabatic deformation or test conditions resulting from heat losses through specimen holders and greater amounts of plastic deformation work at these higher stress levels. Also, the hardness values obtained at −196 C did not fall below the linear function established by the authors. Since the hardness values were obtained under more ideal conditions, it was assumed that they indicated the actual trend of tensile behavior at this temperature.

The Mond curve appears to be valid for the four low-carbon nickel and nickel-chromium steels. However, this trend is contradictory to that established for the other steels and body-centered-cubic metals in general.

In Fig. 6, the increase over the room-temperature hardness is plotted versus the reciprocal absolute temperature. It can be seen that these average points follow the authors' curve to −196 ($1/T = 13.0 \times 10^{-3}$).

Some previous work on plastic flow by

[5] R. L. Smith, R. V. Fostini, and R. M. Brick, "The Low Temperature Properties of Relatively High Purity Iron-Carbon Alloys," *First Progress Report*, Ship Structure Committee, Contract Nos. 50062, Index No. NS-011-078, University of Pennsylvania, Aug. 29, 1952.

[6] W. R. Clough and A. S. Pavlovic, "The Flow, Fracture and Twinning of Commercially Pure Vanadium," *Transactions*, Am. Soc. Metals, Vol. 52 (1960), pp. 948–970.

[7] H. W. Gillet, "Impact Resistance and Tensile Properties of Metals at Subatmospheric Temperatures," Symposium on Impact Resistance and Tensile Properties of Metals at Subatmospheric Testing, *ASTM STP No. 147* Am. Soc. Testing Mats., pp. 102–103 (1941).

the authors[8] has resulted in their obtaining linear functions of the flow stress at constant strain with respect to the reciprocal of absolute temperature that is,

$$\sigma_c = \frac{M}{T} + \sigma_0$$

where:

σ_c = flow stress at constant strain,
M = slope,
T = absolute temperature, and
σ_0 = intercept at $1/T = 0$.

Essentially the same type of function has been used by others in the analysis of the effect of dislocations in yielding.[9,10] Tabor[11] has shown that the Vickers hardness number is directly proportional to the flow stress at approximately a constant strain of 0.08. From the preceding, it would be reasonable to assume that the hardness would also vary linearly with the reciprocal of absolute temperature. Furthermore, the tensile strength would also behave in the same manner provided there were no large changes in the strain at maximum load.

If the tensile strength and hardness can be shown to vary linearly with the reciprocal of absolute temperature, then it follows that a tensile-hardness correlation independent of temperature exists. The authors believe that they have given evidence supporting this conclusion.

[8] F. R. Larson and J. Nunes, "Low Temperature Flow and Fracture Tension Properties of Heat-Treated SAE 4340 Steel," *Transactions*, Am. Soc. Metals, Vol. 53 (1961) pp. 663–682.

[9] J. C. Fisher, "Application of Cottrell's Theory of Yielding to Delayed Yield in Steel," *Transactions*, Am. Soc. Metals, Vol. 47 (1955), pp. 451–562.

[10] N. Louat and H. L. Wain, "Brittle Fracture and Yield Point Phenomenon," *Proceedings*, Conference on Fracture, International Seminar on the Atomic Mechanisms of Fracture, Swampscott, Mass., April 12–14, 1959.

[11] D. Tabor, "The Hardness of Metals," Oxford University Press, Amen House, London, 1951.

The New ASTM System of

Alloy Phase Nomenclature

By W. L. FINK[1] and L. L. WYMAN[2]

With this new system, the culmination of many years' work, Committee E-4 on Metallography hopes to bring order out of chaos.

A VERY SIGNIFICANT EVENT in the metallurgical field is the recent acceptance by ASTM of a Tentative Method for Assigning Phase Designations in Metallic Systems (E 157 –61 T). Up to the time of the development of this tentative, there has been no common system for assigning phase designations. Usually Greek letters have been employed, although frequently upper-case Roman letters or chemical formulas were used. Sometimes the letters were assigned to phases (known to the author at the time of publishing a description of the alloy system) in alphabetical order from either end of a binary diagram or from a corner of the ternary diagram holding particular interest at the moment. The discovery of new phases or the appearance of the (structurally) same phases in other systems would then lead to changes in the designation. Some authors assign the same letter to like phases in different systems regardless of the position of the phase in the diagram. As a result, so many designations are assigned to a given phase in the same and different systems that they have no meaning except in the particular article in which they are assigned.

Committee E-4 Steps in

In the hope of bringing order out of this chaotic situation, Committee E-4 on Metallography has been working for many years to devise a method of assigning phase designations that would be unique and descriptive. After quite some time spent in "idea" gathering, Subcommittee III of Committee E-4, with members from different countries, was formally established in 1949 for the specific purpose of formulating a system for assigning unique designations of metallic phases which would be brief, unambiguous, and "usable" in speech and in writing. After eight years of effort in this direction, the subcommittee agreed upon a proposal. In order to elicit wider international comment and suggestions, the details of this proposal and its development were published in the December, 1957, issue of the ASTM

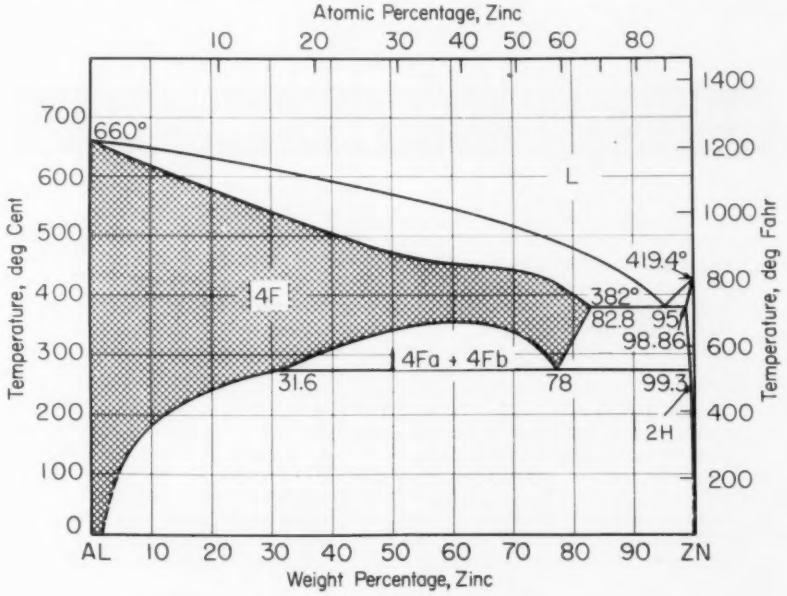

FIG. 1.—DIAGRAM OF THE ALUMINUM-ZINC SYSTEM

[1] Chairman, Subcommittee III on Nomenclature of Committee E-4 on Metallography.
[2] Chairman, Committtee E-4 on Metallography.

BULLETIN under the title, "What Can Be Done to Improve Alloy Phase Nomenclature?" The Society sent reprints of this article to many scientific societies in this country and abroad asking for comments and suggestions. The proposal was generally well received, but there were some excellent suggestions that were incorporated in the revised method. Also, there were other suggestions involving more complicated embellishments that will be discussed in a later paragraph.

The committee has, in the intervening years, brought this proposal to the stage where it has received the approval of many eminent metallurgists throughout the world, the unanimous approval by letter ballot of Subcommittee III[2a], unanimous approval by letter ballot of Committee E-4, and official approval of the Administrative Committee on Standards for issuance as the "Tentative Method for Assigning Phase Designations in Metallic Systems" (E 157 – 61 T).[3]

The New System

The designation is in two parts. The first consists of the chemical symbols of the elements necessary for the formation of the phase. These are placed in parentheses in the order of decreasing atomic percentage and are separated by commas. On phase diagrams, where the chemical elements are obvious and space is limited, this first part of the designation may be omitted (see Fig. 1), but in compiling tables of properties or of etching charts, or for the indexing of powder patterns, the entire symbol will, of course, be used.

The second part of the designation is based on crystal structure. It generally consists of a capital letter and a preceding arabic numeral. The capital letter shows the type of lattice, and the arabic numeral denotes the number of atoms in the unit cell.

Although this system will generally result in a designation consisting of a few chemical symbols, one capital letter, and one arabic numeral, there are some cases requiring special treatment—for example, the addition of a lower-case letter. These special cases are described in Method E 157.

This method fills a long-felt need. Over the years, letters to the editor have appeared in technical magazines in the metals field recommending that a uniform system be adopted. Various systems were proposed and used in certain publications, for example, the Alcoa system for phases in aluminum-base alloys, the system used by Max Hansen and K. Anderko in the second edition of *The Constitution of Binary Alloys*, and the system used by the late W. Guertler in his compilation of ternary diagrams.[4] Many of the metallurgists who have expressed the need for a system or who have proposed one have now approved the one described in Method E 157.

World-Wide Adoption Seen

In view of the need for and the extensive approval of this new method it is anticipated that world-wide use will be achieved in due course. In fact, substantial progress in this direction has already been made. Sigmund Weissmann, associate editor of the ASTM X-ray Card Index, has reported to the Joint Committee[5] that the lack of an adequate system of phase nomenclature for metals and alloys was most confusing in the indexing of powder patterns, and moved that the new method be used by the Joint Committee as soon as officially approved by the Administrative Committee on Standards. The Joint Committee adopted this motion.

While this system is still tentative, it is planned to maintain contact with the societies and with metallurgists who have cooperated in its development in order to make any necessary modifications and to assist in the international adoption of this new system. Although no modifications of the basic two-part system are under consideration at this time, there have been a number of suggestions to the effect that, primarily for the benefit of metallurgists and others deeply concerned with the crystallography of phases, it would be of definite advantage to supplement the present designation. To this end, a task group has been established to study these suggestions and to make suitable recommendations.

Acknowledgments:

The members of Committee E-4 most deeply appreciate the lengthy efforts of P. A. Beck, first chairman of Subcommittee III, and thank their many metallurgical associates from abroad for their wholesome advice and continued support of this project.

[2a] Members: K. W. Andrews, P. A. Beck, R. S. Busk, W. L. Fink, Max Hansen, William Hume-Rothery, F. Laves, Taylor Lyman, J. S. Marsh, G. V. Raynor, F. N. Rhines, C. S. Smith, A. J. C. Wilson.

[3] Published as separate reprint.

[4] W. Guertler, "A Compendium of Constitutional Ternary Diagrams of the Metallic Systems," *Technical Report 58-615*, Wright Aeronautical Development Div., March, 1959.

[5] Joint Committee on Chemical Analysis by Powder Diffraction Methods.

COMING MR&S PAPERS

Loss of Moisture from Fresh Mortars to Bricks—J. I. Davison, National Research Council of Canada.

The Development of More Stable Gage Blocks—M. R. Meyerson, T. R. Young, and W. R. Ney, National Bureau of Standards.

The Identification and Determination of Natural and Manufactured Fibers—S. S. Praeger (deceased).

A Small Panel Method for Investigating Moisture Penetration and Bond Strength of Brick Masonry—T. Ritchie, National Research Council of Canada.

The Effects of Temperature on Air Aging of Rubber Vulcanizates—M. G. Schoch, Hewitt-Robbins, Inc., and A. E. Juve, The B. F. Goodrich Research Center.

A Study of the Centrifuge Test for Determining the Cement Content of Fresh Concrete—Stanton Walker, D. L. Bloem, R. D. Gaynor, and J. R. Wilson, National Ready Mixed Concrete Assn.

Compression Testing of Gypsum Plaster—E. H. Waters and R. Birtwistle, Commonwealth Scientific and Industrial Research Organization of Australia.

The Slow Growth and Rapid Propagation of Cracks—Second Report of Special Committee on Fracture Testing of High-Strength Metallic Materials.

ASTM Publication Wins Acclaim

THE SECOND EDITION of the *Manual on Industrial Water and Industrial Waste Water*, STP 148D, has been selected as one of the 100 best technical books of 1960 in a competition sponsored by *Library Journal*. The selection was made on the basis of appearance, editorial excellence, and contribution to the technical literature.

Library Journal, published by the R. R. Bowker Co., is circulated to over 16,000 librarians in public and private libraries. The competition to select the 100 best technical books is held annually by the journal.

The *Manual on Industrial Water and Industrial Waste Water* is sponsored by Committee D-19 on Industrial Water, of which Max Hecht is chairman. R. D. Hoak headed the subcommittee responsible for the preparation of the manual.

Specifications and the Law

By HERBERT F. LAYLE[1]

HOWEVER DEVOUTLY I might wish to give a clear, concise, useful definition of a specification that is lawful in all respects, such cannot be. This is because what is perfectly proper in one case may be illegal in another. What, therefore, I hope to do is to point out some danger areas, some things to avoid; suggest some ways of meeting some requirements of law; discuss some cases which are of interest; and bring some measure of praise and comfort to ASTM.

When I say that a specification might be perfectly valid in one instance and wholly improper in another, I have first in mind the differences between contracts made by an individual on his own behalf; those made by a private-enterprise corporation; and those made to which an agency of government is a party.

Individual Contracts

The individual, when entering into a contract to have, say, a home built for himself, has the maximum freedom of choice, that is, more than either a corporation or a government agency. We shall see why in a moment.

The one compelling restriction on the individual's freedom is the building code of the municipality where he wishes to build. He is not entirely free—but let us leave talk of building codes until later. There is nothing in the law to prevent the prospective home owner from having the plans and specifications drawn in such a way as to leave the contractor or supplier no choice whatever in the use of materials. He may, for example, specify the manufacturer of pipe, the stock number, grade, and quality of pipe—excluding all other makes and brands. He may specify "X" brand of plumbing fixture—Kohler, American Standard, Crane, or other —giving exact catalog stock number. The contractor simply fixes his bid price knowing what the owner wants. The owner, or his architect or engineer on his behalf, will likewise choose all materials to go into the home as a matter of design, weighing such things as unit stress, safety factors, and costs. The engineer's judgment or discretion is controlling, subject of course to building codes. A customary way in home building is simply to provide an allowance for many features, then leave the owner free to pick the specific brick, light fixtures, plumbing fixtures, etc., that he chooses. The lump sum bid is then adjusted to provide the final contract price if the materials chosen cost more or less than the allowances. This may be done in cases of businesses or government, but it is more common there to prepare alternates, in advance of bidding.

Corporation Contracts

Does the corporation have equal freedom? The answer is no. This is because other factors intervene. These factors are the antitrust laws, laws against monopoly, and restraint of trade. The effect of intercorporate relations has been the subject of much litigation. And this has frequently grown out of accusations from producers who have been excluded from some market.

In this connection, I am amazed at the nature and extent of the activities of the Federal Trade Commission. A recent case that interested me, because it had to do with a relatively insignificant item and a trade association, is the Jos. Dixon Crucible Co. et al case, No. 29 FTC 749. The respondents in the case were some twelve manufacturers of lead pencils and the Lead Pencil Assn., Inc. The FTC issued a cease and desist order saying, in effect, that the respondent companies must cease investigating or consulting with each other with respect to a standardization program having as its objective the limitation of the styles, grades, or qualities of wood-cased lead pencils manufactured and offered for sale by any of them. However, two or more of the respondents could investigate and consult each other for the purpose of working out a simplification program whether done in conjunction with the National Bureau of Standards or among the respondents, provided such investigation or consultation was not for the purpose of effectuating any agreement or combination to fix or maintain prices.

Thus, we see that the use of technical specifications in even so limited a field as wood-cased lead pencils may lead to difficulty if it can be shown that this specification had a direct influence on price fixing or limiting production.

In this connection the Supreme Court has held that a contract that restrains trade is not necessarily illegal, if it is merely ancillary to an otherwise lawful purpose.

This is not to say that a corporation may never specify precisely the product it may want. Take, for example, a plant expansion. If a plant is already equipped with machines of a given make, the company may not wish to consider any other because their operating and maintenance personnel are trained in the use of the installed machinery. A different make could lead to confusion, stocking of excessive parts, and special training for workers. Although the added equipment might run into millions of dollars, the engineers and, therefore, management would have complete authority to exercise their discretion. We can readily see the difference between this situation and one in which a substantial portion of the market for materials is, over a long period of time, dominated by one or a few suppliers because standards or specifications have been designed to restrict purchases for reasons not clearly related to efficient operation.

The recognized authority of the engineer to exercise discretion in the selection of materials to meet his design requirements has not gone unchallenged.

Consider the Ohio Turnpike case. The engineers designing that highway, after considering such things as original cost, longevity, operating and maintenance costs, safety, and other pertinent factors, recommended the use of portland-cement concrete for the paved surface. The commissioners agreed, and accordingly bids were invited on plans specifying that material. Parties interested in asphalt or bituminous concrete brought an action in the Ohio courts to compel the commissioners, and therefore their engineers, to prepare the bidding documents so as to provide for an alternate which would permit the use of bituminous concrete as a paving surface if the bids were more favorable. They were successful in the lower court, but on appeal the Ohio Supreme Court in reversing the lower court said, in effect, "The commissioners and their engineers had the right to specify what they considered to be best, provided only that their action was taken in good faith and not in abuse of discretion."

This case demonstrates that it is the duty and responsibility of the engineer to select and specify the materials out of which his designed product will be made. But this discretion may be challenged and then denied if it appears

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that the engineer had considerations other than safety and efficiency in mind in so specifying.

Government Contracts

With respect to government contracts, there are many provisions of law which make it extremely difficult for a governmental agency, Federal, State, or local, to be restrictive in its specifications. These provisions are designed to prevent favoritism.

In designating materials to be used the engineer has great latitude in the exercise of his judgment. When, for the sake of clarity and simplicity, he designates by trade name, he will be expected to give a selection to those who can provide materials or equipment which accomplish the desired purpose. He may specify by brand or trade name and even stock number. Should there be several suppliers, he may name all of them or name one and follow it by "or approved equal." From the wording of the specification it must appear that the job is not unnecessarily restricted to a product of one company.

In this connection I suggest not the use of the words "approved equal" but the use of the words "approved equivalent." No two branded products are exactly equal in all respects. The word "equivalent" is a better expression of what is meant.

Sometimes, to avoid naming a material by the name of the manufacturer, the engineer may carefully draft a specification in such language that one and only one product, patented or otherwise, will meet the requirement. This can be done legally in some cases, but not all. The procedure is risky because it really fools no one concerned and is recognized as a proprietary type of specification. When the engineer desires the use of one and only one material or product, he should be prepared to defend his judgment on sound technical grounds, not mere prejudice; else if the specification is challenged by those unable to get the business, the engineer may be embarrassed by accusations and by having his judgment overruled on the grounds that it was not exercised in good faith and is an unreasonable restraint of trade or lessening of competition.

One additional comment on "approved equivalent." The specifications, or the contract in some other place, should make clear who is to do the approving when a product other than a named one is to be used by the contractor. Normally, this should be clearly indicated as a function of the engineer.

I recall an instance of a contractor ordering and having received some heavy fire fighting equipment of a make not named in the specification. When asked why he did not first get approval, he replied that it *was* approved—by Underwriters Laboratories. He was out of pocket some heavy shipping costs when he was shown the provision for approval by the engineer and that the equipment would not satisfy a peculiar requirement of the job.

Use of Standards in Building Codes

The Building Officials Conference of America have prepared an extensive Basic Building Code, which is designed to be a model code, and which has been adopted in whole or in part by the code authorities of many municipalities. The code makes great use of some 83 accredited authoritative agencies, including ASTM. For example, where concrete is to meet certain compression tests, reference will be to, say, ASTM Method C 136 – 46. These codes are enacted or adopted by municipalities under the exercise of police powers with a view to protecting the safety of the public, prevent fraud, and preserve civic pride.

When the code authority prescribes that a structure must be built of certain materials meeting prescribed standards of unit stress, fire resistance, and the like, they are substituting their judgment for that of the engineer and to that extent limiting his choice.

In the event that a supplier of a particular commodity finds that his product cannot be used because the code specifies the use of a material meeting a standard established by ASTM, he may feel that the manufacturers of materials which do meet the code, the code authorities, BOCA, and ASTM, have teamed up against him. The normal procedure for the developer of a new product, is to establish the merits of his product by appropriate tests conducted by responsible, independent laboratories.

In cases of building code use it is reasonable to assume that the ASTM standard is *solely* a statement of the quality of a given material and the specified method of testing to determine that quality. Presumably, ASTM had no direct influence on the code authority or the engineer in the *selection* of the given material for a specific use.

Full Speed Ahead

In view of the legal pitfalls besetting the specification writer, someone may ask, "What are we to do?" Well, certainly we shall not stop technological progress merely for fear of "getting in the grease," legally or otherwise. Neither shall we seriously slow down while some enormously expanded legal staff reviews every written word. Were this done, the fun and thrill of developing things would disappear. Committees of ASTM must realize a great satisfaction from devising the specifications for a test of a material, which test will enable all engineers, purchasers, code authorities, and contractors concerned to move with confidence. A real measure of value has been established. It is a revelation of truth which facilitates the work of those who, otherwise, would be put to the impossible task of devising their own detailed specifications for every important purchase.

The authority of the engineer or purchaser to exercise discretion and judgment in the choice of materials must be preserved. The use of ASTM and similarly determined standards is, in reality, a means of preserving this authority. When the vendor of a new material seeks acceptance, it is his obligation to demonstrate the truths of his product. Today, an important part of sales expense is the cost of research and analysis by reliable laboratories, universities, and the like, which seek to establish fitness of the material for proposed uses.

Drafting specifications in this age of specialism can be very complicated, but it is hardly fitting to expect every engineer to be a lawyer, nor would that be desirable, because such a person would tend to be too conservative. He would know too many things that "could not be done."

German Study Team Visits ASTM Headquarters

A TEAM OF EXPERTS from the German construction industry visited ASTM Headquarters on March 9, as part of a four-week tour to study the problems and accomplishments of the construction industry in the United States and Canada, especially those relating to construction through the winter months. Staff members explained to them the history and activities of the Society, giving special attention to the work being done in relation to materials for construction.

Upon their return to Germany, the members of the mission will report on their findings and experiences. The report will be printed by the German Productivity Center and made available to interested parties. Lectures and seminars will be undertaken by members of the team to disseminate these experiences to all persons in Germany concerned with construction.

The team of ten members was headed by Walter Budelmann, president and owner of his own contracting firm in Newmünster, Germany. The visit was arranged under the auspices of the Federal Republic of Germany and the Rationalisierungs-Kuratorium der Deutschen Wirtschaft, through the cooperation of the Council for International Progress in Management (USA), Inc., New York, N. Y.

Society Affairs

64th Annual Meeting

Atlantic City, N. J. — June 25–30, 1961

More like a three-ring circus than ever, this year's Annual Meeting will be a crowded week devoted to what's new in materials research, concurrent with meetings of more than 50 technical committees.

TO THE CASUAL OBSERVER, the ASTM Annual Meeting would seem to be dominated by the busy program of luncheons, lectures, panel discussions, and the some 125 papers to be presented at usually overlapping technical sessions. But the main show goes on behind the scenes, in scores of meetings of technical committees and their subgroups, who are busily revising and adding to the vast body of ASTM standards to keep them modern and useful.

The 1961 Annual meeting is shaping up as follows:

Technical Program

There is something for nearly everyone among the technical sessions, symposia, and panel discussions on the schedule. For the construction industry, there will be eight papers on soil dynamics, five each on soils and road and paving materials; seven on cement, and nine on concrete. For the nuclear industry, 13 papers are now scheduled for three sessions on radiation effects in refractory fuel components. In addition, three panel discussions will be held—on irradiation test methods, on nuclear standardization activities, and on the effect on materials of naturally occurring space radiation.

For power-generation people, there will be three papers on impurities in steam and four on erosion and cavitation. For everyone in the field of materials, the Materials Sciences Division will sponsor five papers on the major effects of minor constituents on the properties of materials, including metals, ceramics, organics, liquids, and gases. These five papers will be presented in two sessions to provide ample opportunity for discussion.

For all who are concerned with the properties of metals, there will be four papers on steel, four on non-ferrous metals, and nine on fatigue. On the subject of evaluation of metals for service at low temperature, 15 papers are scheduled, plus a panel discussion among the authors and others. Nine papers will deal with high-temperature properties, plus six more on compression testing of sheet metals at high temperatures. Other papers will discuss recent developments in metals analysis and electron metallography.

Lectures

Bruce Chalmers, Harvard University, will present the Marburg Lecture on the subject of nucleation and growth of ice crystals. A. B. Kinzel, Union Carbide Corp., will discuss the nature, history, purpose, and use of specifications in his Gillett Memorial Lecture.

The Provisional Program . . .

of the 64th Annual Meeting, which begins on p. 295, is designed to give a comprehensive preview of the sessions, symposia, and special events of the meeting.

The official program given to registrants at the meeting will contain full and final details of the sessions, a complete schedule of committee meetings, and the when and where of social events of the week.

Luncheons

The President's Luncheon on Tuesday noon will feature an address by retiring President A. Allan Bates. This will be followed by a Society business meeting.

Various Society honors and awards will be presented at the Awards Luncheon to be held on Wednesday noon. Past-president Richard T. Kropf will serve as toastmaster.

Committee Meetings

A detailed schedule of technical committee meetings will be included in the program distributed at the Annual Meeting. An advance tentative outline of the meetings was included in the March 30 letter to members. As that letter states, members should consider the committee meeting schedule to be tentative; the official notice for committee and subcommittee meetings will be issued by the secretary of each committee. As we go to press, the following committees plan to meet:

A-1	Steel
A-3	Cast Iron
A-5	Corrosion of Iron and Steel
A-7	Malleable-Iron Castings
A-9	Ferro-Alloys
A-10	Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys
B-2	Non-ferrous Metals and Alloys
B-3	Corrosion of Non-ferrous Metals and Alloys
B-4	Metallic Materials for Thermostats and for Electrical Resistance, Heating, and Contacts
B-5	Copper and Copper Alloys, Cast and Wrought (Subcommittees)
B-6	Die-Cast Metals and Alloys
B-7	Light Metals and Alloys, Cast and Wrought
C-1	Cement
C-4	Clay Pipe
C-7	Lime

C-9 Concrete and Concrete Aggregates
C-11 Gypsum
C-12 Mortars for Unit Masonry
C-15 Manufactured Masonry Units
C-17 Natural Building Stones
C-23 Sorptive Mineral Materials
C-24 Joint Sealants
D-1 Paint, Varnish, Lacquer, and Related Products
D-2 Petroleum Products and Lubricants
D-4 Road and Paving Materials
D-5 Coal and Coke
D-6 Paper and Paper Products
D-8 Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses
D-9 Electrical Insulating Materials
D-11 Rubber and Rubber-Like Products
D-16 Industrial Aromatic Hydrocarbons and Related Materials
D-18 Soils for Engineering Purposes
D-19 Industrial Water
D-20 Plastics
D-24 Carbon Black
D-25 Casein and Similar Protein Materials
D-26 Halogenated Organic Solvents
E-1 Methods of Testing (Subcommittees)
E-2 Emission Spectroscopy
E-3 Chemical Analysis of Metals
E-4 Metallography
E-6 Methods of Testing Building Constructions
E-7 Nondestructive Testing
E-9 Fatigue
E-10 Radioisotopes and Radiation Effects
E-11 Quality Control of Materials
E-12 Appearance
E-15 Analysis and Testing of Industrial Chemicals
E-16 Sampling and Analysis of Metal Bearing Ores and Related Materials
E-18 Sensory Evaluation of Materials and Products
F-1 Materials for Electron Tubes and Semiconductor Devices
Administrative Committee on District Activities
Joint Committee on Effect of Temperature on the Properties of Metals
Advisory Committee on Corrosion
Council of Division of Materials Sciences

NO, THIS IS NOT ATLANTIC CITY, BUT BERMUDA, SITE OF WEEK-LONG ASTM POST-ANNUAL MEETING CONFERENCE.

Dinner Dance

The Philadelphia District Council will sponsor a dinner dance on Wednesday, June 28. Included in the evening's program will be several outstanding entertainment acts. Dance music will be furnished until midnight. A buffet dinner will be served in the Carolina Room of the Chalfonte.

Ladies' Program

An extensive program for the ladies has been planned by their hosts, the Philadelphia District Council. There will be no ladies' registration fee.

Monday through Thursday, a coffee hour will be held on the Lanai Deck of Chalfonte, with members of the District Council's Ladies Committee as hostesses. On Monday evening, Society President A. Allan Bates will give a slide-illustrated talk based on his tour of the Soviet Union. Dr. Bates will give an inside view of the Soviet Union as he found it.

On Thursday morning there will be a tour of the famous Renault Wineries. Those present will watch champagne in the making and will be able to sample the product at the end of the tour. Then a luncheon at a seaside country club, followed by a talk on interior decorating. Total cost for the day will be $3 per person.

Throughout the week, free tickets will be given to ladies who register for a sight-seeing boat trip along the Atlantic City coastline.

Ladies are invited to attend the President's Luncheon on Tuesday, as well as the dinner, entertainment, and dance on Wednesday evening. Tinius Olsen II is chairman of the Ladies' Entertainment Committee.

Philadelphia Airport Limousine Service

Members will be interested to know that the Salem Transportation Co., Traymore Hotel, Atlantic City, N. J., provides a limousine service between the Philadelphia Airport and Chalfonte Haddon Hall. The limousines leave the Philadelphia Airport at 10:00 a.m., 1:00 p.m., 5:00 p.m., and 7:00 p.m. They leave Chalfonte Haddon Hall at 7:00 a.m., 12:30 p.m., 4:00 p.m., and 7:00 p.m. The charge is $5 per person. Reservations must be made in advance with Salem Transportation Co.

Bermuda Conference

Charter buses will leave Chalfonte Haddon Hall at 2:30 p.m. on Friday, bound for Idlewild Airport and Cunard Eagle Airways Flight 108 to Bermuda. Those who have registered for this post-meeting conference will spend eight enjoyable days and seven relaxing nights.

Technical features of the Bermuda conference will include talks by James Smith and Robert Ede on the geological and architectural aspects of engineering and construction in Bermuda. Mr. Smith is deputy director of the Government Department of the Board of Works in Bermuda. There will also be visits to construction sites and to the Bermuda Quarry and the Watlington Water Works.

The remainder of the week in Bermuda will be available for such activities as swimming, sunning, dancing, excellent food, water skiing, sailboating, and calypso and other entertainment. The Princess Hotel is itself a complete resort, with swimming pool and tennis courts, and it extends privileges and transportation to Riddell's Bay Golf Club.

ASTM Sixty-fourth Annual Meeting

Atlantic City, N. J. **Provisional Program** *June 25–30, 1961*

TECHNICAL SESSIONS

MONDAY June 26	TUESDAY June 27	WEDNESDAY June 28	THURSDAY June 29	FRIDAY June 30
MORNING				
1 Session on Fatigue **2 Symposium on Soil Dynamics** Technical Session on Electron Metallography	**9 Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service** **10 Session on Fatigue (*Cont.*)** **11 Symposium on Radiation Effects in Refractory Fuel Compounds**	**20 Symposium on Extension of Sensitivity for Determining Various Constituents in Metals** **21 Symposium on Radiation Effects in Refractory Fuel Compounds (*Cont.*)** **22 Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service (*Cont.*)** —11:30 a.m.— **23 Committee Report Session** (Reports C-16, C-18, C-19, C-20, C-21, C-22, D-22, D-23)	**30 Symposium on Elevated - Temperature Compression Testing of Sheet Materials** **31 Session on General Testing**	**39 Symposium on Microviscometry**
	—12:00 noon— **12 Luncheon Presidents Address and Business Session**	—12:00 noon— **24 Awards Luncheon**	—11:30 a.m.— **32 Committee Report Session** (Reports D-7, D-10, D-12, D-13, E-1, E-10, E-12, E-16)	
AFTERNOON				
3 Symposium on Effects of Minor Constituents on the Properties of Pure Materials —4:30 p.m.— **4 Committee Report Session** (Reports A-6, A-7, A-9, B-1, B-3, B-8, B-9, D-3, E-11)	**13 Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service (*Cont.*)** **14 Symposium on Radiation Effects in Refractory Fuel Compounds (*Cont.*)** —4:30 p.m.— **15 Committee Report Session** (Reports A-10, B-4, B-6, C-4, C-17, C-24, E-3, E-4, F-1)	**25 Symposium on Extension of Sensitivity for Determining Various Constituents in Metals (*Cont.*)** **26 Session on High Temperature (*Cont.*)** **27 Session on Steel** Panel Discussion on Nuclear Standardization Activities —4:30 p.m.— **28 Committee Report Session** (Reports A-1, A-2, B-2, B-5, D-1, D-5, D-17,) **29 Committee Report Session** (Reports C-2, C-3, C-7, C-9, C-12, C-13, D-8, D-18, E-6)	**33 Symposium on Erosion and Cavitation** **34 Session on Non-ferrous Metals** Panel Discussion on the Effect on Materials of Naturally Occurring Space Radiation	—12:30 p.m.— **40 Committee Report Session** (Reports D-2, D-4, D-9, D-11, D-15, D-16, D-19, D-26, D-27) **41 Committee Report Session** (Reports C-1, C-11, E-2, E-5, E-7, E-13, E-15, E-17)
—5:00 p.m.— **5 Marburg Lecture Bruce Chalmers, The Nucleation and Growth of Ice Crystals**	—5:00 p.m.— **16 Gillett Lecture A. B. Kinzel**		—4:30 p.m.— **35 Committee Report Session** (Reports A-3, A-5, B-7, C-15, D-6, D-14, D-20, D-25, F-2)	—2:30 p.m.— **Bus leaves for post-meeting Bermuda conference**
EVENING				
6 Symposium on Effects of Minor Constituents on the Properties of Pure Materials (*Cont.*) **7 Session on Soils** **8 Session on Concrete**	**17 Session on High Temperature** **18 Session on Concrete (*Cont.*)** **19 Panel Discussion on Irradiaton Test Methods (*Cont.*)**	**Dinner-Dance Entertainment**	**36 Session on Cement** **37 Session on Road and Paving Materials** **38 Symposium on Impurities in Steam** Panel Discussion on Temperature Measurement in the Missile and Space Field Panel Discussion on District Activities	

First Session, Monday, June 26, 9:30 a.m.

(Held simultaneously with Second Session)

Session on Fatigue

A Proposed New Relation for Cumulative Fatigue Damage in Bending—S. S. Manson, A. J. Nachtigall, and J. C. Freche, National Aeronautics and Space Administration.

A procedure is proposed for determining the remaining fatigue life of specimens subjected to a prior history of cyclic bending stresses. The method can be applied either graphically or analytically, the only requirement being knowledge of a characteristic constant which is readily obtainable by laboratory tests or which can be estimated.

Fatigue tests of electric-furnace-melted SAE 4130 steel corroborated the hypothesis proposed, which is based upon the assumption that lines representing the S-log N relationship of material prestressed varying amounts will intersect the S-log N line of the original material near a common point.

A Study of the Accumulation of Fatigue Damage in Steel—W. H. Erickson and C. E. Work, Michigan College of Mining and Technology.

Specimens of SAE 4340 steel were prestressed in fatigue for various numbers of cycles at one stress amplitude and retested to failure at various other amplitudes.

Results show that damage was not a linear function of the number of repetitions of stress. Damage resulting from any given prestressing history was not unique but depended on subsequent stresses used to evaluate it.

The observed behavior was explained in terms of a characteristic number of crack nuclei formed by initial cycles of stress and propagation of cracks from these nuclei. The number of crack nuclei formed was controlled by the initial stress amplitude. The rate of crack propagation was controlled by the stress amplitude during later cycles. Total life was governed by both factors.

The Influence of Loading Sequence on Cumulative Fatigue Damage of 7075-T6 Aluminum Alloy—H. T. Corten and Robert Spitzer, University of Illinois.

For conditions of fluctuating stress amplitude consisting of repeated blocks of cycles of two stress amplitudes and continuously varying amplitudes, it has been shown that the mean fatigue life may be predicted using the linear summation of cycle ratios and a "modified σ-N relation." Recent studies by Naumann and Hardrath suggest however, that the sequence of applying high, intermediate, and low stresses in repeated block experiments may change the fatigue life by a factor of from 2 to 4. In this investigation, changing the sequence from high followed by low stresses to low followed by high stresses in each repeated block did not change the life by more than the length of one repeated block of cycles, or by a factor of from 1.07 to 1.14.

A Relation Between Theoretical Stress Concentration Factor and Fatigue Notch Factor Deduced from the Concept of Highly Stressed Volume—Roberto Kuguel, University of La Plata; on Research Fellowship, University of Illinois.

Size and shape effects in existing fatigue data are accounted for by a simple analysis based on the fact that a decrease in fatigue strength accompanies an increase in the volume of material subjected to at least 95 per cent of the maximum stress. A linear relation is established between the logarithm of the maximum stress and the logarithm of the appropriated volume, which is equally valid for smooth and notched members. Based on this analysis, the fatigue notch factor is expressed as a function of the theoretical stress concentration factor, the root radii of the notched and unnotched specimens, and the diameters of the specimens. This is proposed as a simple, adequate relation for use in design.

(Continued in Tenth Session)

Second Session, Monday, June 26, 9:30 a.m.

(Held simultaneously with First Session)

Symposium on Soil Dynamics

The impetus to study soil dynamics is due mainly to the increased speeds and loads of present-day vehicles affecting highway subsoils and also to the practice of dynamic precompaction of subsoils. A determination of basic dynamic soil values, such as modulus of elasticity, energy dissipation, and resonance phenomena, are of fundamental importance. Both the practicing engineer and the theoretician have a stake in answering the question: Can we develop a mathematical model or dynamic analogy that will enable us to predict the behavior of soils subjected to vibratory loads?

The papers in this symposium discuss many of the current concepts in the areas of stress-deformation-time relationships and test instrumentation and measurement.

Testing Procedures for Model Footings and Presentation of Tradex Data—J. A. Alai, Radio Corporation of America.

On Biaxial Stress Field in Noncohesive Soils Subjected to Vibratory Loads—R. K. Bernhard, Rutgers University.

Stress-Deformation Relations for Soft Saturated Silt Under Low-Frequency Oscillating Direct Shear Forces—F. J. Converse, Converse Foundation Engineering Co.

Dynamic Loading Device and Results of Preliminary Small-Scale Footing Tests—R. W. Cunny and R. C. Sloan, U. S. Army Engineer Waterways Experiment Station.

Performance of Embedded Pressure Gages Under Static and Dynamic Loadings—A. J. Durelli and W. F. Riley, Armour Research Foundation.

Bearing Capacities of Dynamically Loaded Footings—S. Shenkman and K. E. McKee, Armour Research Foundation.

Facilities for Dynamic Testing of Soils—G. K. Sinnamon and N. M. Newmark, University of Illinois.

The Damping Capacity of Some Granular Soils—G. F. Weissmann and R. R. Hart, Bell Telephone Laboratories, Inc.

Monday, June 26, 9:30 a.m.

Technical Session on Electron Metallography

A group of papers on electron metallography will be sponsored by Subcommittee XI on Electron Metallography of Metals of Committee E-4 on Metallography.

Third Session, Monday, June 26, 2:30 p.m.

Symposium on Effects of Minor Constituents on the Properties of Pure Materials

This symposium, part of a continuing program of the Division of Materials Sciences, weaves a common thread horizontally through all the states of matter—solids, liquids, gases—and gives occasion for the metallurgist, the ceramist, the organic chemist, the plasma physicist, and the engineer in all these areas to hobnob together in intellectual sociability. The objective is to review and find common gound, not to present new knowledge.

Impurity Effects in High-Purity Metals—L. L. Wyman and G. A. Moore, National Bureau of Standards.

Obtaining metals of the highest possible degree of purity is a problem of major concern in both science and engineering. The determination of impurities, their effects, and their control demand extreme efforts in processing and analysis. Impurities in metals are characterized by the nature of their occurrence and their effects on host metals. Specific examples illustrate impurity effects in a number of currently important applications.

The Effect of Impurities on the Properties of Ceramic Materials—I. B. Cutler, University of Utah.

Intense interest in the effect of impurities on the properties of nonmetallic materials is quite recent. Even today, ceramic materials other than germanium and silicon are difficult to obtain with foreign atom concentrations smaller than 10 to 100 ppm. Yet it is well recognized that impurities strongly affect such properties as bulk and grain boundary diffusion as evidenced by experiments concerning sintering, grain growth, and recrystallization. Impurities markedly affect electrical and thermal conductivity, optical properties, and chemical reactivity. The influence of impurities on the strength of ceramic materials is not thoroughly understood and is the subject of current interest in many laboratories. The above mentioned properties are the subject of this review. All properties are not described with the same thoroughness since adequate reviews exist in certain areas.

Major Effects of Minor Constituents—Role in Organic Material Structures—J. F. Lontz, E. I. du Pont de Nemours & Co., Inc.

There are numerous similarities between the effects of minor constitutive and additive modifications on organic and on inorganic materials. These are discussed in terms of physical and chemical modifications in relation to processibility, solid-state properties, and environmental endurance.

Organic structures are modified by polydispersity of molecular weight, branched or pendant substituents, interspersion of two or more monomer entities, grafts or appendages of different chemical entities, and by blends or admixtures with other polymers and specific, functional additives. An outline of the latter is presented to provide a convenient division of the major effects into (*a*) physical modification of solid-state and melt properties and (*b*) chemical modification for environmental endurance.

(*Continued in Sixth Session*)

Fourth Session, Monday, June 26, 4:30 p.m.

Committee Report Session

A-6 on Magnetic Properties—A. C. Beiler, chairman.

A-7 on Malleable-Iron Castings—C. F. Joseph, chairman.

A-9 on Ferro-Alloys—S. W. Poole, chairman.

B-1 on Wires for Electrical Conductors—D. Halloran, chairman.

B-3 on Corrosion of Non-ferrous Metals and Alloys—K. G. Compton, chairman.

B-8 on Electrodeposited Metallic Coatings and Related Finishes—C. H. Sample, chairman.

B-9 on Metal Powders and Metal Powder Products—J. L. Bonanno, chairman.

D-3 on Gaseous Fuels—D. V. Kniebes, chairman.

E-11 on Quality Control of Materials—Simon Collier, chairman.

Fifth Session, Monday, June 26, 5:00 p.m.

The Nucleation and Growth of Ice Crystals

Marburg Lecture, presented by Bruce Chalmers, Harvard University

The purpose of the Edgar Marburg Lecture is to have described at the Annual Meetings of the Society, by leaders in their respective fields, outstanding developments in the promotion of knowledge of engineering materials. Established as a means of emphasizing the importance of the function of the Society of promoting knowledge of materials, the Lecture honors and perpetuates the memory of Edgar Marburg, first Secretary of the Society, who placed its work on a firm foundation and through his development of the technical programs brought wide recognition to the Society as a forum for the discussion of properties and tests of engineering materials.

Sixth Session, Monday, June 26, 8:00 p.m.

(*Held simultaneously with Seventh and Eighth Sessions*)

Symposium on Effects of Minor Constituents on the Properties of Pure Materials (*Cont.*)

The Problem of Gas Purity in Plasma Research and Technology—S. J. Buchsbaum, Bell Telephone Laboratories, Inc.

This paper discusses high-purity gases, or gases with controlled impurities, as they relate to plasma physics and to plasma technology. Emphasis is on the reasons for the need for high purity, rather than on the ways of achieving it. The point of view is that of a physicist doing research in plasma physics.

Effects of Small Amounts of Extraneous Materials on the Properties of Petroleum, Petroleum Products, and Related Liquids—H. M. Smith, U. S. Bureau of Mines.

Some of the effects of "extraneous" materials, either occurring naturally or added deliberately, in the following classes of materials are considered: crude oil, gasoline, jet fuels, cracking stock, organic compounds (hydrocarbons, sulfur and nitrogen compounds) and oil field waters.

Included among the "extraneous" materials considered are: asphaltenes, hydrocarbons, sulfur and sulfur compounds, nitrogen compounds, porphyrins, metals, antioxidants, antiknock compounds, gums, metals, various anions and cations in aqueous solution, detergents, bacteria, and water.

Some of the effects noted are: corrosion, catalyst poisoning, surface chemistry effects, viscosity effects, induction system fouling, electrical conductivity, antiknock performance, inaccurate physical, spectral, and thermodynamic properties, identification of oil field waters, characterization of crude oil and its fractions.

ASTM methods applicable to some of these problems will be mentioned and areas for research suggested.

Seventh Session, Monday, June 26, 8:00 p.m.

(*Held simultaneously with Sixth and Eighth Sessions*)

Session on Soils

Presentation of Hogentogler Award.

Some Observations on the Measurement of Sensitivity of Clays—W. J. Eden and J. K. Kubota, National Research Council of Canada.

Sensitivity should be a better criterion of soil properties than measures such as the liquidity index. Yet no critical values of sensitivity have appeared that would distinguish a clay subject to earthflows from one that is not. It may be that the present methods of measuring sensitivity lack the necessary precision.

In this paper four methods of measuring sensitivity, the field vane, the unconfined compression test, the laboratory vane, and the fall-cone test, are described. Results of the four methods are compared, using observations on a number of borings in Leda clay. The sensitivities ranged from 1 to over 300 in the borings. There was considerable discrepancy between the results obtained by the four methods.

Strain Effects on Shearing Resistance of Sensitive Clay—C. B. Crawford, National Research Council of Canada.

When sensitive clays are strained in the triaxial test the measured pore water pressure continues to increase after the specimen has been subjected to the maximum possible deviator stress. Because of this, the computed angle of shearing resistance in terms of effective stresses continues to increase and may reach a maximum value 50 per cent greater than that computed at maximum deviator stress. The angle is shown to be at least partly dependent on strain at failure.

By causing failure through a variety of stress paths and observing specimens after failure it may be argued that the reason for this controversial angle of shearing resistance is the migration of water through the specimen during testing. Test results are presented to support this argument. The selection of a satisfactory failure criterion is discussed.

Unconfined Compressive Strength Values in a Series of Soil-Additive Strength Determinations—H. T. David, D. T. Davidson, and C. A. O'Flaherty, Iowa State University.

In unconfined compression testing three specimens are normally tested and the average of the three obtained strengths is reported. Any measurement which deviates by more than 10 per cent for the average of the three determinations is usually discarded. This 10 per cent limit needs to be reappraised, since entirely valid triplicate strength values may attain this percentage by virtue of expected statistical fluctuation.

This paper outlines procedures which attempt to control the rate of wrongful disqualifications by replacing the 10 per cent disqualifying limit by a percentage that is based upon the coefficient of variation and is specific to the investigation at hand. A criterion is also given for assessing the reliability of the results as a whole.

Quantitative Determination of Soil Montmorillonite by X-Ray Diffraction—G. R. Glenn, Southern Illinois University, and R. L. Handy, Iowa State University.

Montmorillonite exerts a strong influence on soil properties. This paper reports an attempt to measure accurately the per cent montmorillonite from selected Iowa Soils. The results are discussed in relation to particle size, plasticity, glycol retention, and cation exchange data. Special procedures were used to obtain random orientation of soil grains in the sample holders. A measured amount of internal standard was added to each sample. Better accuracy and intensities were obtained without ethylene glycol treatment. Diffraction intensity using peak area for the mineral are compared with the standard. Curves are prepared so that a value for montmorillonite peak area may be adjusted according to the moisture condition of the soil, determined by X-ray diffraction from the mean *d*-spacing. A calibration curve was prepared from which percentage montmorillonite may be determined by the ratio of adjusted mineral peak area to internal standard area for the particular soil.

A Study of Artificial Soils—E. T. Selig and R. D. Rowe, Armour Research Foundation.

A study of artificial soils was undertaken to determine: (1) the variety of properties that can be obtained with artificially prepared soils, (2) the reproducibility and stability of these properties, and (3) the extent to which these properties resemble those of natural soils. Soils synthesized from clay minerals, nonclay soil minerals, and water, ethylene glycol, or mineral oil in many different combinations were examined using standard soil identification procedures. It is concluded that artificial soils can exhibit a wide variety of natural soil properties that are reproducible and stable, and that for general laboratory studies not requiring a specific natural soil, particularly where a standard soil is desired for purposes of comparison, the use of artificial soils appears promising.

Eighth Session, Monday, June 26, 8:00 p.m.

(Held simultaneously with Sixth and Seventh Sessions)

Session on Concrete

The Indirect Tension Test for Concrete—N. B. Mitchell, Jr., Cornell University.

This paper evaluates the use of the indirect tension test for concrete and other brittle materials. Present and proposed tension testing procedures are compared theoretically and experimentally with the indirect tension test.

The influence of plate size and plate type on the failure of cylinders is considered. General test procedures are suggested, and tests on high-strength concrete cylinders and Keene's cement cylinders are reported to verify the theoretical conclusions.

Correlation of Flexural and Compressive Strengths of Concretes and Mortars—K. E. Palmer and I. L. Lynn, Ideal Cement Co.

Statistical correlations of various flexural and compressive strengths of laboratory-prepared concretes and mortars using 37 Type I, II, and III cements from different parts of the United States are reported.

The investigation covers mortar compressive strengths for cubes and flexural strengths of bars. Concrete compressive strengths are for cylinders and flexural strengths are for midpoint loading of bars. Test ages were 3, 7, 28, and 90 days, and Type III cements included 1-day tests.

Highly significant correlation equations for several strength relationships are presented for each of the cement types studied and for a combination of the three cement types.

Strain Distribution in Compressively Loaded Concrete Specimens—J. R. Keeton, U. S. Naval Engineering Laboratory.

Strain distribution in compressively-loaded concrete cylinders was determined with mechanical strain gages, resistance strain gages, and with cantilever deflection-type devices employing resistance strain gages. Unique arrangement of the strain-measuring devices enabled definition of longitudinal strain distribution in increments as short as 0.10 in., with stresses up to 4000 psi.

Additional studies using PhotoStress confirmed the surface strain distribution determined by other strain measuring methods and shed considerable light on the function of aggregate and mortar in distributing internal strains in the concrete.

Methods for Determining Mechanical Resonance Frequencies and for Calculating Elastic Moduli from These Frequencies—S. Spinner and W. E. Tefft, National Bureau of Standards.

The first part of this paper describes the latest techniques for exciting, detecting, and measuring the mechanical resonance frequencies of specimens. The methods are applicable to any material having a low enough value of internal friction to be set into resonance. These include metals, ceramics (including glass), and concrete. Accuracies of one part in 4000 in resonance frequency are readily attainable.

Part II describes methods for computing the appropriate elastic moduli from these resonance frequencies, for specimens of the shapes most frequently used experimentally (cylindrical rods and rectangular bars). These methods of computation are designed to be at least as accurate as the best reasonably achievable experimental data. Tables for facilitating these calculations are included.

(Continued in Eighteenth Session)

Ninth Session, Tuesday, June 27, 9:30 a.m.

(Held simultaneously with Tenth and Eleventh Sessions)

Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service

This symposium has been prepared in response to the continually increasing interest in low-temperature processes, transportation of liquefied gases, and the use of these products in the rocket and missile industry. The demand by design engineers for further information on the properties of materials at cryogenic temperatures is especially acute in the field of metals, the most important materials of construction for the storage, processing, and distribution of fluids at extremely low temperatures. There is as yet neither a clear classification of metals nor a simple test procedure to assist the designer in his selection of metals for all conditions of stress at climatic and lower temperatures.

This symposium will present recent concepts in low-energy brittle fracture of metals together with suggested research to develop these concepts, and an interpretation of laboratory data of new test work not only on the commonly used metals but also on many of the newly developed metals and alloys.

Analysis of the Effects of Test Temperature on the Notch Strength of High-Strength Sheet Alloys—Volker Weiss and J. G. Sessler, Syracuse University.

Welded Ferritic Steel Construction for Intermediate Low-Temperature Service: Considerations Arising from Tension Tests of Welded and Notched Wide Plates—A. A. Wells, British Welding Research Assn.

Effect of U-Notch Depth on Impact Resistance Under Simple Beam Loading—D. C. Reymond, Esso Research and Engineering Co.

The Effect of Small Cracks on the Load-Carrying Ability of High-Strength Steel—G. K. Manning, Battelle Memorial Inst.

Tensile and Impact Properties of Cast Stainless Steels at Cryogenic Service—E. R. Hall, Esco Corp. *(To be presented by title only).*

(Continued in Thirteenth and Twenty-second Sessions)

Tenth Session, Tuesday, June 27, 9:30 a.m.

(Held simultaneously with Ninth and Eleventh Sessions)

Session on Fatigue *(cont.)*

Tensile, Bending-Fatigue, and Axial-Fatigue Properties of 5052-H39 Aluminum Foil Laminates—F. W. Forbes, Wright Air Development Div.

Laminated sheet panels composed of a number of layers of 5052-H39 aluminum foil oriented in various fashions with respect to one another and bonded with various adhesives were tested in tension and in fatigue. Properties of these laminates were compared with the properties of solid sheet of the same material. Density of the laminates was 3 to 7 per cent less than that of the solid sheet. The strength-to-density ratio of the laminates was 4 to 7 per cent higher than that of the solid sheet. Bending and axial fatigue tests showed the laminates to be superior at all stress levels to the solid sheet materials, on the basis of stress over density versus number of cycles.

Effect of Oleophobic Films on Fatigue Crack Propagation—W. L. Holshouser and H. P. Utech, National Bureau of Standards.

Sharply notched rotating beam specimens were used to evaluate the effect of dodecyl alcohol on the rate of fatigue-crack propagation in 4340 steel, 17-7 PH stainless steel, 6061-T6 aluminum alloy, and a copper 1.75 per cent beryllium alloy. The number of cycles required to propagate the crack was increased by the presence of the organic compound by factors ranging from 1.35 to 4.96. This effect is attributed to the ability of compounds of this type to form films that protect the metal from extraneous molecules of oxygen and water vapor.

A Fatigue Test for Printed Circuit Boards and Through Connections—G. R. Goltz and A. Fox, Bell Telephone Laboratories, Inc. *(To be presented by title only.)*

This paper describes how a Krouse plate fatigue testing machine was modified to permit the fatigue testing of printed circuit boards and through connections such as those used in miniature and microminiature designs. A special monitoring circuit using a transistorized relay to indicate failure in the conductors is also described, and typical test data are presented to show the usefulness of the test.

Fatigue Properties of Uncoated and Coated Unalloyed Molybdenum at 1800 F, Room Temperature, and −40 F—A. A. Mittenbergs and D. N. Williams, Battelle Memorial Inst., and G. D. Haley, Wah-Chang Alloys Co.

Fatigue behavior of unalloyed, commercially pure, arc-cast molybdenum was investigated in tension-tension loading on uncoated and coated, unnotched and notched sheet specimens at 1800 F, room temperature, and −40 F. Three oxidation-resistant coatings were evaluated under fatigue loading. Static tension tests were also conducted on specimens with the four surface conditions at the three temperatures.

For unprotected specimens, the unnotched fatigue strength at 10^7 cycles (maximum stress) was 28,000 psi at 1800 F, 90,000 psi at room temperature, and 127,000 psi at −40 F. The notch sensitivity was low at 1800 F, but rather high at room temperature and −40 F. All coatings lowered the fatigue strength somewhat at all three temperatures. The loss of fatigue strength was higher in the notched specimens.

The Endurance Properties of Steel Rope Wire as Related to the Contained Impurities, Ductility, and Structure—J. N. Kenyon, Fatigue of Materials Laboratory.

Fatigue data obtained on preformed wire, taken from seven brands of improved plow steel rope and straightened, showed no essential differences due to contained impurities. There were some differences as related to cold bend, impact, and other physical properties, but largely within the limits of experimental error. Certain deductions are drawn as to why certain wire should have pronounced higher fatigue strengths.

Eleventh Session, Tuesday, June 27, 9:30 a.m.

(Held simultaneously with Ninth and Tenth Sessions)

Symposium on Radiation Effects in Refractory Fuel Compounds

The necessity of developing fuel materials which will withstand operation at temperatures in the range of about 2000 F and above has focused attention on refractory fuel compounds. The standard fuel material of this nature has been uranium dioxide, both in bulk and dispersion form. However, new fuel compounds, such as uranium monocarbide and dispersions of uranium dioxide in beryllium oxide are rapidly being developed. A considerable amount of data is being generated concerning several basic problems in the use of these fuels.

This symposium will provide a means of dissemination and discussion of the latest data available concerning the effects of radiation on the properties of refractory fuel compounds. Such data will be directed, in so far as possible, toward an understanding of the basic mechanisms that produce damage in refractory fuel compounds as a result of the fissioning process.

Some Consequences of Excess Oxygen in UO_2—J. A. L. Robertson, Atomic Energy of Canada, Ltd.

Void Formation in Irradiated UO_2—J. L. Bates, General Electric Co.

The Heat Rating Required to Produce Central Melting in Various UO_2 Fuels—A. S. Bain, Atomic Energy of Canada, Ltd.

Fission Fragment Tracks in UO_2—T. S. Noggle and J. O. Stiegler, Oak Ridge National Laboratory.

Sintering Characteristics in a Radiation Environment—E. A. Aitken, General Electric Co.

(Continued in Fourteenth, Nineteenth, and Twenty-first Sessions)

Twelfth Session, Tuesday, June 27, 12:00 Noon

Luncheon Session

President's Address—A. Allan Bates, Portland Cement Assn.
Recognition of Honorary Members
Business Meeting
Report of the Board of Directors—T. A. Marshall, Jr., Executive Secretary.
Amendment to By-laws—Article VIII, Dues:
Amend Section 5 by the deletion of the italicized words.
Sec. 5. Any person elected after six months of any fiscal year shall have expired, may pay only one-half of the amount of dues for that fiscal year; *but in that case he shall not be entitled to a copy of the Proceedings for the current year.*
Other Business.

Thirteenth Session, Tuesday, June 27, 2:30 p.m.

(Held simultaneously with Fourteenth Session)

Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service *(cont.)*

Steels of Improved Fracture Toughness—J. M. Hodge, U. S. Steel Corp.

Testing Techniques and Evaluation of Materials for Use at Liquid Hydrogen Temperatures—R. Markovich and F. Schwartzberg, The Martin Co.

The Correlation of Notch:Unnotch Tensile Ratios with Tensile Fatigue Properties of Complex Welded Joints in High-Strength 300 Series Stainless Steels at Cryogenic Temperatures—J. F. Watson, T. T. Tanalski, and A. Hurlich, Convair Astronautics.

Factors Influencing the Fracture Toughness of Sheet Materials for Use in Lightweight Cryogenic Tankage—G. B. Espey, M. H. Jones, and W. F. Brown, National Aeronautics and Space Administration.

Design of Cryogenic Storage for Industrial Applications—H. W. Marsh, Graver Tank and Manufacturing Co.

Brittle-Fracture Transition of Some Concrete Reinforcing Steels—A. L. Tarr, U. S. Army Research Office.

Fracture of High-Strength Sheet Steel Specimens Containing Small Cracks—J. E. Srawley and C. D. Beachem, U. S. Naval Research Laboratory. *(To be presented by title only.)*

(Continued in Twenty-second Session)

Fourteenth Session, Tuesday, June 27, 2:30 p.m.

(Held simultaneously with Thirteenth Session)

Symposium on Radiation Effects in Refractory Fuel Compounds *(cont.)*

Study of the Factors Controlling the Release of Xe^{133} from Bulk UO_2—D. F. Toner and J. L. Scott, Oak Ridge National Laboratory.

In-Pile Release of Fission Products in UO_2—J. B. Neleham and F. A. Rough, Battelle Memorial Inst.

The Continuous Release of Fission Gas from UO_2 During Irradiation—R. M. Carroll, Oak Ridge National Laboratory.

(Continued in Nineteenth and Twenty-first Sessions)

Fifteenth Session, Tuesday, June 27, 4:30 p.m.

Committee Report Session

A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys—L. L. Wyman, chairman.

B-4 on Metallic Materials for Thermostats and for Electrical Resistance, Heating and Contacts—E. I. Shobert II, chairman.

B-6 on Die-Cast Metals and Alloys—W. Babington, chairman.

C-4 on Clay Pipe—C. R. Velzy, chairman.

C-17 on Asbestos-Cement Products—W. V. Friedlaender, chairman.

C-24 on Joint Sealants—W. F. Koppes, chairman.

D-24 on Carbon Black—N. P. Bekema, chairman.

E-3 on Chemical Analysis of Metals—Arba Thomas, chairman.

E-4 on Metallography—L. L. Wyman, chairman.

F-1 on Materials for Electron Tubes and Semiconductor Devices—S. A. Standing, chairman.

Sixteenth Session, Tuesday, June 27, 5:00 p.m.

Exploitation of Rare Materials

Gillett Lecture, presented by A. B. Kinzel, Union Carbide Corp.

This lecture, established in 1951, is jointly sponsored by ASTM with Battelle Memorial Inst. It commemorates Horace W. Gillett, one of America's leading technologists and metallurgists and the first director of Battelle. The lecture is delivered annually at a meeting of the Society, the first one having been given at the Fiftieth Anniversary Meeting, June, 1952. The lecture will cover subjects pertaining to the development, testing, evaluation, and application of metals.

Seventeenth Session, Tuesday, June 27, 8:00 p.m.

(Held simultaneously with Eighteenth and Nineteenth Sessions)

Session on High Temperature

Apparatus for Obtaining Mechanical Properties at High Temperatures—D. H. Fisher, R. L. Carlson, and F. C. Holden, Battelle Memorial Inst.

An apparatus for obtaining mechanical properties of refractory materials at temperatures above 2000 F is described. The loading apparatus, vacuum furnace, specimen designs, and the methods used for temperature and strain measurement are detailed. Specimens are heated by radiation from a resistance-type tubular heater. Optical systems are used for temperature and strain measurement. Stress-strain relationships to about 0.5 per cent strain were obtained. Typical results are presented.

Elevated-Temperature Dynamic Moduli of Metallic Materials—W. H. Hill, K. D. Shimmin, and B. A. Wilcox, Wright Air Development Div.

Elevated-temperature dynamic moduli of elasticity of 40 commercial metals and alloys at temperatures ranging up to 1800 F are presented. The paper describes the design, construction, and operation of an electrostatic device for measuring dynamic modulus under conditions of longitudinal resonance. Measurements were made under conditions of continuous heating at a nominal rate of 12 F per min. Materials tested included aluminum alloys, beryllium, titanium alloys, steels, stainless steels, a cobalt alloy, nickel alloys, and refractory metals and alloys. Room-temperature comparisons of dynamic with static moduli are given in most instances. Results also show the variations of modulus with temperature and alloy composition in a series of vanadium-titanium alloys.

The Applications of Rabotnov's Creep Parameter—R. M. Goldhoff, General Motors Co.

Rabotnov's suggested equation for correlating isothermal creep data is:

$$\phi(\epsilon) = \sigma(1 + at^b)$$

where: σ = stress, t = strain time, b = constant, and $\phi(\epsilon)$ and a are functions of strain.

The applicability of this equation to various materials, its sensitivity to the variables involved, and its potential as a design tool are examined. It is concluded that excellent correlations can be developed if certain precautions are observed. The method is potentially highly useful in design work.

Determination of Compressive, Bearing, and Shear Creep of Sheet Materials—J. R. Kattus and H. L. Lessley, Southern Research Inst.

This paper describes the facilities to determine the compressive, bearing, and shear creep properties of sheet metals up to about 1000 F. The compression and bearing tests are carried out in loading fixtures that contain cartridge heaters as integral parts. These heating units, which obviate the need for conventional furnaces, provide extremely good temperature uniformity. Accurate strain measurements are facilitated because the extensometer can be positioned quite close to the specimen, eliminating mechanical errors that occur in the long extension arms required with furnace heating. Shear creep-rupture tests are carried out on both sheet-type and pin-type specimens in conventional creep furnaces. Examples are given of the results obtained on titanium alloys.

(Continued in Twenty-sixth Session)

Eighteenth Session, Tuesday, June 27, 8:00 p.m.

(Held simultaneously with Seventeenth and Nineteenth Sessions)

Session on Concrete *(cont.)*

Application of Epoxy Healants for Repairing Structural Cracks in Concrete Members—C. M. Wakeman, Port of Los Angeles.

This paper deals with the laboratory and field tests preceding the selection of epoxy resins for the restoration of large concrete members in a marine environment. Some large structural cracks appeared in a number of concrete pile caps in a wharf at the Port of Los Angeles. The alternate to healing the cracks with epoxy resin would be to demolish the wharf deck and reconstruct the beams and deck with new concrete. It was estimated that the epoxy bonding procedure would cost only 50 per cent of the price for reconstruction. Preliminary testing of the cracked concrete and field and laboratory tests leading to the selection of epoxy resins are described.

Variation on Pozzolanic Behavior of Fly Ashes—R. D. Vincent, Manuel Mateos, and D. T. Davidson, Iowa State University.

The objectives of this investigation were to determine the relative effectiveness as pozzolans of different fly ashes economically available in Iowa, and to try to correlate strength of lime-fly ash mixtures with various fly ash properties by isolating groups of fly ashes having several similar properties.

Twenty-two fly ashes mixed with a calcitic hydrated lime and with a dolomitic monohydrate lime were studied to determine optimum moisture contents for maximum 7-day strength and maximum standard Proctor dry density of each mixture. Specimens were molded at moisture contents which were compromises between optimum moisture contents for maximum strength and maximum dry density. Correlation studies were then made to determine the influence of lime and fly ash properties on strength of lime-fly ash mixtures.

Concrete Containing Fly Ash as a Replacement for Portland Blast-Furnace Slag Cement—W. E. Grieb, Bureau of Public Roads.

This investigation was made to determine the effect of the use of fly ash as a replacement for part of the portland blast-furnace slag cement on the strength and durability of concrete. Four cements were used: a type I portland and a type IS portland blast-furnace slag cement from two cement mills. Two fly ashes were used, one with a low carbon content and the other with a high carbon content. Two methods were used for designing the mixes containing fly ash.

These tests show that fly ash used as a replacement for portland blast-furnace slag cement had approximately the same effect on strength and durability as when used with portland cement.

Testing Uniformity of Large Batches of Concrete—D. L. Bloem, R. D. Gaynor, and J. R. Wilson, National Ready Mixed Concrete Assn.

Tests were made of multiple samples from 51 full-size batches of ready-mixed concrete to develop methods for studying within-batch uniformity. Comparisons of the following characteristics were made at various locations within each batch: slump, unit weight, air content, coarse aggregate content, cement by centrifuge separation, water content by drying, sand-aggregate ratio, mixing water content, water-cement ratio, and compressive strength. The number of samples per batch ranged from 2 to 12. Procedures were varied to compare field testing conditions with those in the laboratory. Multiple tests of the same kind on the same sample were made in some cases to provide information on their reproducibility. A straightforward and indicative method is suggested for evaluating within-batch uniformity.

Modern Concepts in Control of Concrete—J. J. Waddell, Knoerle, Graef, Bender and Associates, Inc.

After a brief grouping of the agencies that are destructive to concrete, the five steps to good concrete are described. These are investigation of the site, design of the structure, selection of the materials and mix, control of the materials and concrete, and observation of the structure throughout its life.

To the concrete engineer on the site, control of the materials and concrete is the most important step. Fundamentals of quality concrete construction are discussed, together with a review of the functions of the quality control engineer. A plan for control of ready-mixed concrete is presented which can be executed by local segments of the industry itself.

Nineteenth Session, Tuesday, June 27, 8:00 p.m.

(Held simultaneously with Seventeenth and Eighteenth Sessions)

Symposium on Radiation Effects in Refractory Fuel Compounds *(cont.)*

Panel Discussion on Irradiation Test Methods

(Continued in Twenty-first Session)

Twentieth Session, Wednesday, June 28, 9:30 a.m.

(Held simultaneously with Twenty-first and Twenty-second Sessions)

Symposium on Extension of Sensitivity for Determining Various Constituents in Metals

Recent metallurgical research and development efforts have been increasingly directed toward determining the effects of very small amounts of various elements on the physical and mechanical properties of metals. Present analytical methods will suffice for determining certain trace constituents. However, in many instances new techniques are needed not only for determining elements that are homogeneously present in minute amounts, but also for analysis of elements present in high local but low average concentrations.

The papers in this symposium discuss separation of desired constituents from matrix and interfering elements prior to certain chemical and spectrographic determinations, and describe recent progress in radioactivation, electrochemical, spectrographic, electron microprobe, and solids mass spectrometric analysis.

Separations in Analysis—J. L. Hague, National Bureau of Standards.

Recent Developments in Electroanalytical Chemistry—Louis Meites, Polytechnic Institute of Brooklyn.

Radioactivation Analysis: A Sensitive and Specific Method for Metals Analysis—G. W. Leddicotte, Oak Ridge National Laboratory.

(Continued in Twenty-fifth Session)

Twenty-first Session, Wednesday, June 28, 9:30 a.m.

(Held simultaneously with Twentieth and Twenty-second Sessions)

Symposium on Radiation Effects in Refractory Fuel Compounds *(cont.)*

Irradiation of BeO-UO_2 Fuel Pellets—D. E. Johnson, J. Koretzky, and A. K. Smalley, Battelle Memorial Inst.

Irradiation Effects in Uranium Monocarbide—D. G. Freas, A. E. Austin, and F. A. Rough, Battelle Memorial Inst.

Effects of Burnup on Certain Ceramic Fuel Materials—M. L. Bleiberg, W. Yeniscavich, and R. G. Gray, Bettis Atomic Power Laboratory.

Hydrolysis of Beryllia—C. C. Browne, General Electric Co.

Irradiation Behavior of PuO_2 Fast Oxide Breeder Fuel—J. N. Siltanen, J. M. Gerhart, and J. S. Cochran, General Electric Co.

Twenty-second Session, Wednesday, June 28, 9:30 a.m.

(Held simultaneously with Twentieth and Twenty-first Sessions)

Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service *(cont.)*

Testing and Design Considerations for Brittle Fractures—Sumio Yukawa, General Electric Co.

Influence of Sheet Thickness on the Sharp Edge Notch Properties of a β Titanium Alloy at Room and Low Temperatures—A. J. Repko, M. H. Jones, and W. F. Brown, National Aeronautics and Space Administration. *(To be presented by title only.)*

Discussion of presentations by authors and the following panel members:
G. R. Irwin, chairman of panel, U. S. Naval Research Laboratory.
Robert Stout, Lehigh University.
P. P. Puzak, U. S. Naval Research Laboratory.
John Low, Jr., General Electric Co.

Summary Statement—G. R. Irwin.

Twenty-third Session, Wednesday, June 28, 11:30 a.m.

Committee Report Session

C-8 on Refractories—J. J. Hazel, chairman.

C-16 on Thermal Insulating Materials—W. C. Lewis, chairman.

C-18 on Natural Building Stones—F. S. Eaton, chairman.

C-19 on Structural Sandwich Constructions—Steven Yurenka, chairman.

C-20 on Acoustical Materials—R. N. Hamme, chairman.

C-21 on Ceramic Whitewares and Related Products—N. T. Morrison, chairman.

C-22 on Porcelain Enamel—W. N. Harrison, chairman.

D-22 on Methods of Atmospheric Sampling and Analysis—J. Cholak, chairman.

D-23 on Cellulose and Cellulose Derivatives—F. A. Simmonds, chairman.

Twenty-fourth Session, Wednesday, June 28, 12:00 Noon

Awards Luncheon

Awards of Merit, Recognition of 40-, 50-, and 60-Year Members, Dudley Medal Award, Richart, Templin, Thompson, and Tour Awards.

Twenty-fifth Session, Wednesday, June 28, 2:30 p.m.

(Held simultaneously with Twenty-sixth and Twenty-seventh Sessions)

Symposium on Extension of Sensitivity for Determining Various Constituents in Metals *(cont.)*

Ultratrace Emission Spectroscopy—G. H. Morrison and R. L. Rupp, General Telephone and Electronics Laboratories.

Use of the Electron Probe to Measure Low Average but High Local Concentrations—L. S. Birks and R. E. Seebold, U. S. Naval Research Laboratory.

Extension of Sensitivity in the Analysis of Impurities in Solids by Mass Spectrometry—C. M. Stevens, Argonne National Laboratory.

Twenty-sixth Session, Wednesday, June 28, 2:30 p.m.

(Held simultaneously with Twenty-fifth and Twenty-seventh Sessions)

Session on High Temperature *(cont.)*

The Creep and Rupture Properties of Five Copper-Base Casting Alloys—D. P. Moon and W. F. Simmons, Battelle Memorial Inst.

Creep tests were conducted on cast specimens of 76Cu-2½Sn-6½Pb-15Zn, 65,000 psi manganese bronze, 110,000 psi manganese bronze, 20 per cent nickel silver, and 81-4-15 silicon brass alloys at selected temperatures between 250 and 550 F. The duration of the longest tests at each temperature was about 2000 to 3000 hr.

The creep and rupture data were correlated with elevated-temperature, short-time tensile data by means of the ASME Boiler and Pressure Vessel Code criteria. Creep data are also presented in the form of design curves and isochronous stress-strain curves. The stability of these alloys during creep exposure was determined by means of tension tests and metallographic examination after creep exposure.

Anomalous Fracture in the Creep of Nickel—T. C. Reuther, P. Shahinian, and N. R. Achter, U. S. Naval Research Laboratory.

Creep specimens of nickel-base alloys stressed at relatively low levels sometimes fail in the fillet, where the stress is appreciably lower than in the gage section. When this behavior was observed in air but not in vacuum, it was investigated by examining fracture of tapered nickel rods in the two environments at 1200 and 1500 F. These rods ruptured at the minimum section in vacuum at both temperatures and also in air at 1200 F, where oxidation strengthening is slight. At 1500 F in air, however, as the applied stress was reduced and oxidation strengthening increased, the fracture was progressively displaced toward heavier sections. Metallographic studies and measurements of rupture strength as a function of specimen diameter have supported the explanation that strengthening by oxide formation in grain boundaries is more extensive at the smaller sections.

Creep-Rupture Properties of Several Elevated-Temperature Alloys in Helium and Air Environments—F. J. Wall and H. B. Gayley, Westinghouse Electric Corp.

Creep-rupture tests were made on Discaloy, W-545, and D-979 alloys at 1200 F, and Inco 713C at 1300 F, and on Inco 700 at 1500 F in helium and air environments. In all tests, a combination notch-smooth bar specimen was used.

The rupture times under 500 hr (high stresses) for Discaloy, W-545, D-979, and Inco 700 were somewhat lower in helium than in air, while the creep properties were similar. On the longer-time tests (low stresses), there was no apparent difference in the creep-rupture properties between the two environments. The creep-rupture properties of Inco 713C were unaffected by the helium environment at all stress levels.

Elevated-Temperature Fatigue Properties of Several Alloys in Helium and Air Environments—F. J. Wall, H. B. Gayley, and T. F. Hengstenberg, Westinghouse Electric Corp.

Unnotched and notched fatigue properties of several elevated-temperature alloys in air and pure helium environments are presented. All the tests in helium and some of the tests in air were performed on axial-type machines, while most of the tests in air were performed on reversed-bending machines. Alloys and tests temperatures were Inco 713C at 1100 F, 1300 F, and 1500 F; W-545 and D-979 at 1100 F and 1200 F; Inconel X at 1300 F; and Inco 700 at 1500 F.

Unnotched data obtained at 1300 F on Inconel X and Inco 713C in air and helium suggest a lowering of the air fatigue properties in helium.

Properties of Hardened Copper-Beryllium Strip After Exposures to Elevated Temperatures—K. G. Wikle and N. P. Sarle, Brush Beryllium Co.

Tensile properties of copper beryllium alloy 25 strip (1.91Be-0.26Co) in AT and HT conditions were evaluated at room and elevated temperatures after exposure to temperatures of 100 to 1150 F for 0 to 120 hr. Exposures up to 600 F did not reduce room-temperature strength, while those above 600 F caused overaging. Elevated-temperature strength slowly diminished in heating to 500 F and more rapidly above this temperature. Long exposures at 500 F caused further hardening, resulting in highest room-temperature strength at this temperature. Minimum elevated-temperature ductility occurred at 600 F for AT and at 500 F for HT materials. Microstructural changes were evaluated. Properties determined are compared with those of other copper-base alloys.

Wednesday, June 28, 2:30 p.m.

Panel Discussion on Nuclear Standardization Activities

This panel discussion is being sponsored by the special ASTM Administrative Committee on Nuclear Problems to point out the general scope of nuclear standardization activities in the American Society for Testing Materials, American Nuclear Society, American Society of Mechanical Engineers, American Standards Association, and Pressure Vessel Research Council. Also to be discussed will be ways and means of coordinating current and future activities of the groups working on special projects in the various societies.

Twenty-seventh Session, Wednesday, June 28, 2:30 p.m.

(Held simultaneously with Twenty-fifth and Twenty-sixth Sessions)

Session on Steel

The Relationship Between Standard Qualification Tests for Stainless Steel and the Corrosion Behavior of a Nickel-Base Alloy—B. E. Hopkinson and H. R. Copson, The International Nickel Co., Inc.

The paper compares the corrosion behavior of Ni-o-nel nickel-iron-chromium alloy in acid environments with the results of standard qualification tests for stainless steel. This alloy was developed for resistance to sulfuric and phosphoric acids. Its high titanium and low carbon content are intended to produce immunity to intergranular corrosion. However, in some cases sensitization indicated by the Huey 65 per cent nitric acid test can occur. One heat of the alloy, when heat-treated in the sensitizing range and exposed to the qualification tests, gave results indicating sensitization. An attempt was made to identify the sensitizing precipitate by electron microscope examination. To determine the significance of this sensitization in comparison to the behavior in acid environments, corrosion rates in pure acids were determined on the alloy in a sensitized and mill-annealed condition. The results indicate little or no connection between corrosion in pure acids and the performance in qualification tests.

A Specimen for Use in Investigating the Stress-Corrosion Cracking of Austenitic Stainless Steels at 500 to 600 F—H. L. Logan, National Bureau of Standards.

This paper describes a hollow cylindrical specimen with an internal capacity for 11 ml of corrosive, designed so that oxygen can be added to the corrosive. The specimen is loaded in tension, in a conventional creep furnace, by means of a lever system. Photographs of failed specimens are shown. Results obtained on exposure of type 304 stainless steel specimens in the temperature range of 450 to 600 F with constant concentration of corrosive are reported.

A Fractographic Analysis of 4340 Steel Missile Motor Casings—N. A. Tiner, Astropower, Inc.

A study is made of the modes of fracture of 4340 steel missile motor casings. Two methods are used to supplement the visual observation of the fracture pattern for determining the direction of crack propagation. One is the observation of the concavity of the elongated domains on the shear fracture surfaces by electron microscopy, and the other is examination of the secondary crack orientation in the transverse fracture profiles by optical microscopy. Evidence is presented which supports the discontinuous theory of fracture propagation both in transverse and shear types of failure in steels.

Strain Strengthening of Type 304 Stainless Steel—E. E. Weismantel, Walter Hammer, and Leonard Stemann, The Beryllium Corp.

A development program was conducted to produce high-strength austenitic steel bar materials using tensile cold-straining procedures, since cold-worked bars with uniform properties are not commercially available. Test results indicate this process can easily achieve a 100,000-psi tensile yield strength. This strength level could be raised with additional development effort. Based upon the test results, the yield strength in compression is estimated to be approximately 70 per cent of the cold-strained tensile yield strength. Machining, forming, and welding experiments indicate that it is no more difficult to fabricate cold-strained austenitic bar materials than other austenitic materials now in use.

Twenty-eighth Session, Wednesday, June 28, 4:30 p.m.

(Held simultaneously with Twenty-ninth Session)

Committee Report Session

A-1 on Steel—J. J. Kanter, chairman.

A-2 on Wrought Iron—L. S. Crane, chairman.

B-2 on Non-ferrous Metals and Alloys—Alfred Bornemann, chairman.

B-5 on Copper and Copper Alloys, Cast and Wrought—W. H. Jennings, chairman.

D-1 on Paint, Varnish, Lacquer and Related Products—W. T. Pearce, chairman.

D-5 on Coal and Coke—R. L. Coryell, chairman.

D-17 on Naval Stores—S. R. Snider, chairman.

Twenty-ninth Session, Wednesday, June 28, 4:30 p.m.

(Held simultaneously with Twenty-eighth Session)

Committee Report Session

C-2 on Magnesium Oxychloride and Magnesium Oxysulfate Cements—J. B. James, acting chairman.

C-3 on Chemical-Resistant Mortars—J. R. Allen, chairman.

C-7 on Lime—H. F. Kriege, chairman.

C-9 on Concrete and Concrete Aggregates—Bryant Mather, chairman.

C-12 on Mortars for Unit Masonry—H. C. Plummer, chairman.

C-13 on Concrete Pipe—R. R. Litehiser, chairman.

D-8 on Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses—H. R. Snoke, chairman.

D-18 on Soils for Engineering Purposes—W. G. Holtz, chairman.

E-6 on Methods of Testing Building Constructions—R. F. Legget, chairman.

Thirtieth Session, Thursday, June 29, 9:00 a.m.

(Held simultaneously with Thirty-first Session)

Symposium on Elevated-Temperature Compression Testing of Sheet Materials

It has been estimated that 60 to 90 per cent of an airframe must be designed for compression. Most parts are designed so that failure will occur by elastic instability, but compressive yield may be critical where relatively heavy thicknesses and short column lengths are involved.

Compression testing of sheet specimens for determination of yield strength at room temperature is covered by Methods E 9. This standard describes several jigs developed to support thin sheet material. These jigs become unsuitable at elevated temperatures because of increasing friction between the specimen and jig or relaxation of the jig leaving the column unsupported. High heating rates to test temperature also introduce temperature uniformity problems. The papers in this symposium describe methods developed to overcome these problems and present data obtained with these methods.

Introduction—H. C. Turner, Convair.

An Evaluation of Compression Testing Techniques of Sheet Materials at Elevated Temperatures—George Gerard, New York University.

Compression Testing of Sheet Materials at Elevated Temperatures—Ralph Papirno and George Gerard, New York University.

Rapid-Rate Compression Testing of Sheet Materials at High Temperatures—E. C. Bernett and W. W. Gerberich, California Institute of Technology.

Evaluation of Test Variables in the Determination of Elevated-Temperature Compression Yield Strength of Magnesium Sheet—R. W. Fenn, Jr., Dow Metals Products Co.

Compression and Buckling Characteristics of Annealed and Aged Inconel 718 Nickel-Chromium Alloy at Room and High Temperatures up to 1400 F—Julian Dubuc and Georges Welter, Ecole Polytechnique, and V. N. Krivobok, The International Nickel Co., Inc.

An Evaluation of a System for the Compression Testing of Sheet Materials at Elevated Temperatures—W. W. Breindel, R. L. Carlson, and F. C. Holden, Battelle Memorial Inst.

Summary—J. R. Kattus, Southern Research Inst.

Thirty-first Session, Thursday, June 29, 9:30 a.m.

(Held simultaneously with Thirtieth Session)

Session on General Testing

Stress-Relaxation—Some New Test Methods for the Determination of This Mechanical Property Either in Tension or in Compression—G. R. Gohn and A. Fox, Bell Telephone Laboratories, Inc.

The methods of test now used for determining the stress-relaxation characteristics of materials—either in tension or in compression—are reviewed, their limitations discussed, and several new methods developed by the authors are described. Long-time data obtained in both tension and compression tests are presented, and evidence is offered to show why it may be difficult to derive reliable long-time stress-relaxation values from constant-load creep data.

The Effect of Specimen Geometry on Determination of Elongation in Sheet Tension Specimens—E. B. Kula and N. H. Fahey, Watertown Arsenal Laboratories.

The influence of specimen thickness and width on the elongation in 2 in. was studied for SAE 1020 steel and heat-treated H-11 steel. The results conform approximately to Templin's equation, $El = kA^n$. The constant n, a measure of the variation of elongation with specimen area, is shown to be related to the log of the ratio of the zero-gage-length (fracture strain) to the infinite-gage-length (uniform strain) elongations. A method is shown for predicting the elongation for a bar of any thickness (or width) from measurements on another bar of the same material.

The importance of specimen area, rather than absolute values of width or thickness, in controlling elongation is demonstrated by studying the strain distribution near the fracture.

The Effect of Section Size on the Notch Strength and Fracture Development in Selected Structural Metals—E. P. Klier, The Catholic University of America, and Volker Weiss, Syracuse University.

Cylindrical sharp-notch tension specimens up to 2-in. diam were tested at room temperature. Steel, titanium, and aluminum specimens in both strengthened and softened structural conditions were examined to establish the effect of specimen size on notch properties.

The changes in notch geometry at the point of fracture initiation were studied as a function of specimen size for unalloyed titanium. Limited test data show that notch geometry changes must play an important role in the phenomenon of size effect. Crack development in the cylindrical notched specimens is discussed at length. The notched specimens separated first near the base of the sharp notch, but final separation for concentrically loaded specimens resulted ultimately from nucleation of an internal fracture, probably due to ductility exhaustion, which propagated to separation of the specimen.

Potential Heat: A Method for Measuring the Heat Release of Materials in Building Fires—J. J. Loftus, D. Gross, and A. F. Robertson, National Bureau of Standards.

Modifications were made to a method, currently a standard of the French government, for assessing the combustibility of building materials. Standard calorimetric techniques are used in which the burning of small quantities of combustible in an otherwise inert material is assured by use of a combustion promoter. The difference between calorimetric measurements before and after exposure to a "standardized fire" is considered as the potential heat. The test method has been used on a variety of building materials, and results are in general agreement with fire experience.

A Method for Determining the Plastic Flow Properties of Sheet and Round Tension Specimens—John Nunes and F. R. Larson, Watertown Arsenal Laboratories.

An experimental procedure is described for obtaining continuous load-profile measurements of sheet and round tension specimens during plastic flow. Some data obtained on tempered alloy steel, titanium, 301 stainless steel, and an aluminum alloy are presented to illustrate the uses and advantages of this testing method. With this procedure, the following data were obtained from a single testing curve: True stress-strain, true strain rate, mechanical anisotropy, and "corrected" flow stress.

Tests were primarily at room temperature on sheet material; some low-temperature tests were conducted on the 301 stainless steel. A round tension specimen of aluminum was also tested to illustrate a method for determining "corrected" flow stress values according to the Bridgman technique.

Thirty-second Session, Thursday, June 29, 11:30 a.m.

Committee Report Session

D-7 on Wood—L. J. Markwardt, chairman.

D-10 on Packaging—K. W. Kruger, chairman.

D-12 on Soaps and Other Detergents—J. C. Harris, chairman.

D-13 on Textile Materials—H. F. Schiefer, chairman.

E-1 on Methods of Testing—A. C. Webber, chairman.

E-10 on Radioisotopes and Radiation Effects—E. B. Ashcraft, chairman.

E-12 on Appearance—G. W. Ingle, chairman.

E-16 on Sampling and Analysis of Metal Bearing Ores and Related Materials—J. L. Hague, chairman.

Thursday, June 29, 2:00 p.m.

Panel Discussion on the Effect on Materials of Naturally Occurring Space Radiation

A task group was appointed in 1960 by Committee E-10 on Radioisotopes and Radiation Effects to investigate this subject. There will be an extensive report of this investigation as well as a discussion.

Thirty-third Session, Thursday, June 29, 2:30 p.m.

(Held simultaneously with Thirty-fourth Session)

Symposium on Erosion and Cavitation

The subject of erosion and cavitation is very important in hydraulic turbines, diesel engines, and many other applications. Consideration was given to these phenomena in the early part of 1960 by the Administrative Committee on Simulated Service Testing. As a result of these discussions it was decided to organize a symposium to determine the present knowledge of these phenomena. The papers in this symposium describe the theories of the cavitation erosion mechanism, review methods and equipment for accelerated tests for measuring resistance to cavitation, and present the results of years of service experience in the use of various materials to resist cavitation erosion.

The Mechanism of the Deformation of Solids by the Impact of Liquids at High Speeds—J. H. Brunton, University of Cambridge.

Erosion by Liquid Impact—S. M. DeCorso and R. E. Kothmann, Westinghouse Electric Corp.

Accelerated Cavitation Erosion and Sand Erosion—W. C. Leith and W. S. McIlquham, Dominion Engineering Works, Ltd.

Cavitation in Hydraulic Turbines—W. J. Rheingans, Allis-Chalmers Manufacturing Co.

Thirty-fourth Session, Thursday, June 29, 2:30 p.m.

(Held simultaneously with Thirty-third Session)

Session on Non-ferrous Metals

Some Effects of Section Size and Testing Condition on the Tensile Properties of Zircaloy 2 at 600 F—S. L. Ames, Allegheny Ludlum Steel Corp.

Tensile properties at 600 F of annealed Zircaloy 2 in a number of mill product forms vary over quite a wide range. Some of the variations can be attributed to differing degrees of directionality developed in processing. In hot-rolled strip, for example, transverse specimens have lower tensile strengths, higher yield strengths, and greater ductility than longitudinal specimens. Vacuum annealing can cause a deterioration in tensile strength. Oxygen does not appear to have a major effect over the range of 1250 to 1600 ppm. Yield and possibly tensile strengths appear to be dependent on the type of specimens used. Round specimens generally give higher values than flat specimens, while machining of flat specimens to thinner gages also results in an improvement.

Room-Temperature Creep Rate of Molybdenum and Effect of Strain Rate on the Tensile Properties of Molybdenum—R. Q. Barr, M. Semchyshen, and G. A. Timmons, Climax Molybdenum Company of Michigan.

This investigation was made to determine the effect of strain rate on the room-temperature tensile properties of molybdenum. Specimens were annealed prior to testing to obtain either a stress-relieved or a recrystallized structure. Six sets of elastic and plastic strain rates were investigated. The strain rates selected were those which have been suggested or already appear in various specifications.

Yield strengths varied directly with elastic strain rate, and tensile strength was sensitive to plastic strain rate. Ductility was not particularly sensitive to changes in strain rate. The actual strain rate during early stages of load application was found to be substantially different from the crosshead separation rate.

Room-temperature creep tests indicate that unalloyed molybdenum can exhibit measurable creep rates at room temperature at stresses below the yield strength.

Properties of an Annealed Copper-Nickel-Iron Alloy at 600 F—G. H. Eichelman, Jr., Anaconda American Brass Co.

Elevated-temperature properties at 600 F are given for Cupronickel 707, a wrought 30 per cent cupronickel modified by the addition of about 5 per cent iron. The data include tensile, creep, and stress-rupture properties at elevated temperature; tensile properties, conductivity, and corrosion behavior (relative to 70-30 cupronickel) at room temperature; and the coefficient of expansion over the temperature range involved.

Supplied in the annealed and stabilized condition, this alloy has an attractive combination of corrosion and strength properties for unfired pressure vessel applications at the temperature studied.

Tensile Strength-Hardness Correlation for Titanium—Charles F. Hickey, Jr., Watertown Arsenal Laboratories.

Experimental work plus a literature survey were used to establish a correlation between ultimate tensile strength and hardness for titanium alloys of current interest. Tensile strength and hardness properties were changed by varying testing temperature, heat treatment, and section size of material. The following relationship was found to apply to most α-β alloys:

$$UTS = 5050\ R_c - 28{,}000$$

In addition, the following hardness correlation was established between Rockwell and Vickers hardness:

$$VHN = 12.8\ R_c - 104$$

It is interesting to note that data for Ti-16V-2.5Al, a metastable α-β alloy, do not fit either of the above equations, probably because the alloy transforms to martensite upon straining.

Thirty-fifth Session, Thursday, June 29, 4:30 p.m.

Committee Report Session

A-3 on Cast Iron—R. A. Clark, chairman.

A-5 on Corrosion of Iron and Steel—H. F. Hormann, chairman.

B-7 on Light Metals and Alloys, Cast and Wrought—R. A. Harris, chairman.

C-15 on Manufactured Masonry Units—J. W. Whittemore, chairman.

D-6 on Paper and Paper Products—H. A. Birdsall, chairman.

D-14 on Adhesives—A. A. Marra, chairman.

D-20 on Plastics—J. B. DeCoste, chairman.

D-25 on Casein and Similar Protein Materials—L. E. Clark, Jr., chairman.

F-2 on Flexible Barrier Materials—C. C. Sutton, chairman.

Joint Committee on Effect of Temperature on the Properties of Metals—J. J. Kanter, chairman.

Thursday, June 29, 8:00 p.m.

Panel Discussion on Temperature Measurement in the Missile and Space Field

(Sponsored by Subcommittee 32 on Thermocouples for Temperature Measurement of Committee E-1 on Methods of Testing.)

Temperature Determination on the Pershing Missile—D. Booker, P. Moran, and R. Ahearn, The Martin Co.

Spring-Loaded Thermocouple Probes and Transient Temperatures—P. M. Hahn, Lockheed Aircraft Corp.

Panel Discussion

Thirty-sixth Session, Thursday, June 29, 8:00 p.m.

(Held simultaneously with Thirty-seventh and Thirty-eighth Sessions)

Session on Cement

Investigation of Concrete Materials for a Major Project in Western Canada—G. C. Price, Canada Department of Agriculture.

Studies of concrete and mortar were conducted to evaluate sulfate resistance, cement-aggregate reaction, compressive strength, and mix characteristics. Seven type V cements and one type I cement were used with fly ash and pumicite. Mixtures were designed on the basis of fixed cement factor with pozzolan replacing a portion of the aggregate. Trends in performance of concrete, the mortar phase of concrete, and standard sand mortars in mixed sulfate solution are described. A low percentage of reactive "siliceous shalestone" in the processed fine aggregate produced no deleterious effect in concretes and mortars stored in humid air. The effect of pozzolans upon the mix are described and compressive strengths are given for ages to 1 yr. Long-term observations of exposed concretes in sulfate soils have revealed little deterioration where proper techniques in design, manufacture, and placement result in a highly impermeable concrete-in-place.

Improved Adiabatic Calorimeter for Concrete—David Pritz, University of California.

An improved automatically controlled adiabatic calorimeter for determining the temperature rise of mass concrete is described. The calorimeter consists of an outer chamber maintained at a controlled temperature slightly below that of the inner chamber, in order that the inner chamber need never be cooled. A row of resistance thermometers is mounted across the section of the concrete specimen and its immediately surrounding insulation, and the temperature across the specimen is maintained precisely constant.

Structural and operational aspects of the calorimeter are described in detail. Results of adiabatic temperature-rise tests for several concrete mixes are reported. Deviations from true adiabatic conditions and the reliability of temperature measurements are discussed.

The Mechanism of Grinding Aids—F. J. Mardulier, W. R. Grace and Co., Dewey and Almy Chemical Div.

Grinding aids, interground with portland cement clinker at relatively low addition rates, are generally polar compounds. For this reason, they are preferentially adsorbed on reactivity centers of cement surfaces formed probably by fracture of electrovalent bonds and thus reduce the surface-energy forces which cause agglomeration of the newly produced cement particles. The consequent reduction in surface-energy forces causes "dry" dispersion of the cement which in turn increases cement fluidity and in some cases significantly reduces mill retention time. To aid in the control of mill retention time a method for its determination involving the use of fluorescein has been developed. The relationship between mill retention time, circulating load, and ratio of grinding media to clinker charge is shown. An approach to the determination of optimum circulating load is indicated.

Significance of Selected ASTM C-1 Tests

Discussion of Method C 359, Test for False Set of Portland Cement—W. C. Hansen, Consulting Chemist.

This paper reviews the work of the Working Committee on False Set of Committee C-1 on Cement in the development of the Method of Test for False Set of Portland Cement (Mortar Method) (C 359). It presents data which show the stiffening produced in pastes of powdered quartz by the precipitation of small amounts of calcium sulfate. It also presents data obtained by eleven laboratories with Method C 359 on several cements which, in general, show very good agreement.

When there was poor agreement between laboratories, the results indicate that the cements tested by certain of the laboratories were aerated more than those tested by the other laboratories.

Significance of Method C 265, Test for Calcium Sulfate in Hydrated Portland Cement Mortar—T. B. Kennedy, U. S. Army Engineer Waterways Experiment Station.

Work by William Lerch has shown that grinding the correct amount of gypsum with clinker when cement is made results in optimum strength and volume stability. Optimum conditions appeared to correlate with availability of sulfate ions for reaction with tricalcium aluminate for the first 24 hr with little or no sulfate remaining thereafter.

Committee C-1 on Cement established a working committee on sulfur trioxide in 1946 and adopted Method C 265, which provides for chemical analysis of water extracts of hardened cement mortar for soluble sulfate at 24 hr. Experience with Method C 265 has demonstrated that it lacks the reproducibility to permit its use for specification purposes or for control of sulfate in day-to-day production. Other methods based on strength and volume change are being investigated.

Significance of Tests for Sulfate Resistance—William Lerch, Portland Cement Co.

This paper reviews the progress that has been made in the development of a performance test for sulfate resistance of cement. The Tentative Method of Test for Potential Sulfate Resistance of Portland Cement (C 452 - 60 T) appears to be an acceptable performance test for the sulfate resistance of portland cements. Data now available seem to indicate that the test is not suitable for use with portland blast-furnace slag cements. Additional tests now under way will provide further information on that subject.

Flexural Strength of Hydraulic Cement Mortars—M. A. Swayze, Lone Star Cement Corp. (retired).

ASTM Methods using 2 by 2 by 12-in. prisms were adopted in 1954. The specimen size has since been reduced to 40 by 40 by 160 mm. Experience with these 40-mm prisms, when broken in flexure and in compression as modified cubes, has shown excellent uniformity. Tests of both mortar and concrete show that the briquet and the prism flexural test are equally able to predict the concrete flexural strength. However, the prism flexural strengths give a better index of concrete compressive strength.

For Type III cements the mortar compression tests (both cubes and prisms) overestimate concrete strengths. For other cement types the mortar tests underestimate early concrete strengths and overestimate later ones. Strength testing of mortars would be improved if uniform water-cement ratios were used. Also, it seems absurd to continue making two types of strength specimens of different water-cement ratios when the 40-mm prism can supplant both the briquet and the 2-in. cube.

Thirty-seventh Session, Thursday, June 29, 8:00 p.m.

(Held simultaneously with Thirty-sixth and Thirty-eighth Sessions)

Session on Road and Paving Materials

A Laboratory-Field Study of Hot Asphaltic Concrete Wearing Course Mixtures—J. F. Goode, Bureau of Public Roads.

Results of a laboratory-field study of six asphaltic concrete pavements ranging in age from 3 to 12 yr are described.

The Los Angeles abrasion loss for the coarse aggregate ranged from 17 to 39 per cent. Both field compaction and traffic caused slight degradation of the aggregate. The degree of degradation appeared to be related to gradation of entire aggregate as well as to toughness of the coarse aggregate.

Initial pavement air voids ranged from 5.6 to 14.5 per cent. Rate of asphalt aging was related to the number of these voids. Surfaces of pavements containing the greater number of voids deteriorated earlier. The air void criteria of the immersion-compression method of mix design was substantiated.

Significance of Variation of Bitumen Content of Paving Mixtures—J. H. Keyser, Laboratory for Testing Materials, and N. G. Gaudette, State Highway Commission of Wisconsin.

Precise measurement of bitumen content consistency in a paving mixture is limited by the representative state of the sample and the accuracy of the extraction procedure. Many highway agencies use a centrifuge extractor to determine bitumen content. This paper recommends a centrifuge extraction procedure using trichloroethylene as a washing solvent. Modification of the "dust correction" determination procedure allows higher accuracy and is less time-consuming than previous methods.

Centrifuge extraction test results are evaluated statistically for "pavement samples" and for "truck samples." It is concluded that tolerance limits of bitumen content below about ±0.5 per cent of the total mix weight are not realistic.

Rapid Method Proposed for the Determination of Specific Gravities of Porous Asphalt Concrete Cores—L. E. Santucci and R. J. Schmidt, California Research Corp.

The method selected for measuring the volume of laboratory- or field-compacted bituminous concrete cores controls the values obtained for the specific gravity of paving mixtures. In turn, these values are used to determine the void properties and, hence, pavement performance of the mix. This paper recommends a new procedure, referred to as the saturated water method, for measuring volume directly after coring field specimens, thus reducing the time and expense previously required for an accurate volume determination. Data are presented to compare specific gravities determined by the saturated water method with specific gravities obtained by three other methods. It is emphasized that one method must be established as a standard if density measurements are to be a dependable criterion in design.

Air Permeability of Asphalt Concrete at Paving Temperatures—T. C. Hein and R. J. Schmidt, California Research Corp.

Other investigators have indicated the importance of low air permeability of asphalt concrete for increased pavement durability. Portable equipment has been designed and used to measure this pavement characteristic. To be effective as a construction control test, special equipment is described which measures air permeability at paving temperatures. This permits measurements which will indicate when added compaction is necessary at a time when correction is possible. Data obtained in this way show systematic permeability variation as the pavement cools. Laboratory permeability-temperature data are discussed and compared with field results. Procedure for construction control testing is suggested.

Measurement of Asphalt Viscosity with a Vacuum Capillary Viscometer—J. J. Heithaus, Shell Oil Co.

This paper describes the use of vacuum-operated capillary viscometer on bituminous materials. The range of the viscometer is from approximately 10 to 50,000 poises. Thus, it is well suited to the measurement of the viscosity of asphalt cements at 140 F, cutback asphalts at 77 F, and fractions separated from asphalts over a considerable range of temperature. Since the shear rate can be varied, the instrument can be used satisfactorily for measurements on non-Newtonian materials. The theory of the instrument is discussed briefly. Examples of results obtained on typical bituminous materials are given.

Thirty-eighth Session, Thursday, June 29, 8:00 p.m.

(Held simultaneously with Thirty-sixth and Thirty-seventh Sessions)

Symposium on Impurities in Steam

The methods of measurement of impurities in steam have evolved as the maximum tolerable impurities have been reduced from tenths of a per cent to parts per million and now to parts per billion. High steam temperatures and pressures have forced consideration of the significant volatility of salts other than silica. Once-through steam generators present added problems of the solubilities of substances in supercritical water. Increases in sensitivity of the methods of measurement have literally opened Pandora's box on the matter of sampling. The papers in this symposium contribute significantly to our knowledge of this subject.

Introduction—J. K. Rice, Cyrus Wm. Rice & Co.

The Prevention of Errors in Steam Purity Measurement Caused by Deposition of Impurities in Sampling Lines—R. V. Cobb and E. E. Coulter, Babcock & Wilcox Co.

The Stoichiometry of the Vaporous Carry-over of Sodium Chloride from High-Pressure Boiler Water—M. M. Rubright, The Babcock & Wilcox Co.

Impurities in Steam from High-Pressure Boilers—R. C. Ulmer and H. A. Klein, Combustion Engineering, Inc.

Summary—F. E. Clarke, U. S. Naval Engineering Experiment Station.

Thursday, June 29, 8:00 p.m.

Panel Discussion on District Activities

The Administrative Committee on District Activities will sponsor an open panel discussion on district activities. The topics covered will include purposes of districts, program for districts to meet these purposes, student award programs, and financing of district activities. All officers and members of district councils and all others interested in district affairs are invited to attend. This program is part of the effort of ACDA to stimulate greater and more effective district activities.

Thirty-ninth Session, Friday, June 30, 9:30 a.m.

Symposium on Microviscometry

In recent years a new device, the sliding plate microviscometer, has been introduced to determine the absolute viscosity of asphalts in thin films. This equipment and its attendant possibilities for studies of the rheologic behavior of asphalts has received widespread interest from asphalt technologists. Subcommittee B-19 of Committee D-4 on Road and Paving Materials has conducted a series of cooperative tests with this equipment to determine the repeatability and reproducibility of measurements of asphalt viscosity. This symposium will present results of these cooperative tests and illustrate the use of this equipment for measuring the viscosity of asphalt cements at in-service temperatures and for studying the physical behavior of asphalts. In the latter category will be included studies of (1) the rheology of asphalt-mineral filler systems, (2) temperature-viscosity relationships of asphalts and their relationship to pavement construction, and (3) asphalt durability as measured by changes in viscosity in the thin film oven and aging index tests.

Measurement of Consistency of Paving Cements at 140 F with the Sliding Plate Microviscometer—R. L. Griffin and D. F. Fink, Shell Development Co.

The Precision of Measurements with the Sliding Plate Microviscometer—D. F. Fink and J. J. Heithaus, Shell Oil Co.

The Rheology of Asphalt-Filler Systems as Shown by the Microviscometer—R. S. Winniford, California Research Corp.

The Effects of Viscosity in Hot Mix Construction—Verdi Adam, State of Louisiana Department of Highways.

Changes in Asphalt Viscosities During the Thin-Film Oven and Aging Index Tests—W. J. Halstead and J. A. Zenewitz, Bureau of Public Roads.

Fortieth Session, Friday, June 30, 12:30 p.m.

(Held simultaneously with Forty-first Session)

Committee Report Session

D-2 on Petroleum Products and Lubricants—Harold M. Smith, chairman.

D-4 on Road and Paving Materials—R. E. Bollen, chairman.

D-9 on Electrical Insulating Materials—A. H. Scott, chairman.

D-11 on Rubber and Rubber-like Products—Simon Collier, chairman.

D-15 on Engine Antifreezes—R. E. Vogel, chairman.

D-16 on Industrial Aromatic Hydrocarbons and Related Materials—W. E. Sisco, chairman.

D-19 on Industrial Water—Max Hecht, chairman.

D-26 on Halogenated Organic Solvents—W. D. McMaster, chairman.

D-27 on Electrical Insulating Liquids and Gases—E. R. Thomas, chairman.

Forty-first Session, Friday, June 30, 12:30 p.m.

(Held simultaneously with Fortieth Session)

Committee Report Session

C-1 on Cement—R. R. Litehiser, chairman.

C-11 on Gypsum—G. W. Josephson, chairman.

E-2 on Emission Spectroscopy—R. E. Michaelis, chairman.

E-5 on Fire Tests of Materials and Construction—H. D. Foster, chairman.

E-7 on Nondestructive Testing—J. H. Bly, chairman.

E-13 on Absorption Spectroscopy—E. J. Rosenbaum, chairman.

E-15 on Analysis and Testing of Industrial Chemicals—W. A. Kirklin, chairman.

E-17 on Skid Resistance—E. A. Whitehurst, chairman.

Joint Committee on Leather—Joseph Naghski, chairman.

Gordon Research Conferences To Include Meetings on Adhesion and Physical Metallurgy

THE 1961 GORDON RESEARCH Conferences will include a 5-day conference on physical metallurgy in June and a 5-day conference on adhesion in August. The physical metallurgy conference will be held at Kimball Union Academy, Meriden, N. H., June 26–30. The conference on adhesion will be held at New Hampshire School, New Hampton, N. H., August 28–September 1.

The aim of these conferences is to extend the frontiers of science by fostering a free and informal exchange of ideas among persons actively interested in the subjects under discussion. The purpose of each program is to bring experts up to date on the latest developments, to analyze the significance of these developments, and to provoke suggestions concerning the underlying theories and profitable methods of approach for making progress. The review of known information is not desired.

In addition to the conferences on adhesion and physical metallurgy, the following will be held:

At Colby Junior College, New London, N. H.

Petroleum, June 12–16
Catalysis, June 19–23
Nuclear Chemistry, June 26–30
Polymers, July 3–7
Textiles, July 10–14
Elastomers, July 17–21
Corrosion, July 24–28
Separation and Purification, Aug. 7–11
Instrumentation, Aug. 14–18

At New Hampton School, New Hampton, N. H.

Chemistry of Coal, June 12–16
Chemistry and Physics of Liquids, June 19–23

> . . . The research for scientific truth cannot be narrowed but the tabulation of the results and the comprehension of unifying principles can—indeed, must—be reduced to ultimate simplicity. This, to my way of thinking, is a vital application of engineering standards in the fields of science and engineering
>
> "Standards as Engineering Guidance in Design and Development,"
> G. J. Marks,
> ASA Eleventh National Conference on Standards,
> New York, N. Y., Oct. 25–27, 1960

Scientific Information Problems in Research, July 3–7
Magnetic Resonance, July 10–14
Radiation Chemistry, July 17–21
Organic Reactions and Processes, July 24–28
Statistics in Chemistry and Chemical Engineering, Aug. 7–11
Analytical Chemistry, Aug. 14–18
Inorganic Chemistry, Aug. 21–25

At Kimball Union Academy, Meriden, N. H.

Organic Coatings, July 17–21
Chemistry at Interfaces, July 24–27
Solid-State Studies in Ceramics, July 31–Aug. 4
Chemistry and Physics of Solids, Aug. 14–18
Photonuclear Reactions, Aug. 21–25
High-Temperature Chemistry: Molten Salts, Aug. 28–Sept. 1

At Tilton School, Tilton, N. H.

Ion Exchange, June 26–30
Chemistry and Metallurgy of Semiconductors, July 10–14
Microbiological Deterioration, July 17–21
Electrodeposition, July 31–Aug. 4
Electrical and Relaxation Processes in Glass, Aug. 7–11

Requests for information should be sent to W. George Parks, director, Department of Chemistry, University of Rhode Island, Kingston, R. I.

TECHNICAL COMMITTEE NOTES

Flexible Barrier Materials

Committee F-2 on Flexible Barrier Materials met at the Packaging School of Michigan State University on March 8, 1961. A new project to develop standards for regenerated cellulosic films was announced. The early work of this new project will be directed toward the development of standards that demand special methods for testing cellulose films, such as tests for gas permeability and impact.

The group on extraction test methods will concentrate on three promising types of apparatus used to determine the extractables in flexible barrier films. This study will provide the background necessary to initiate interlaboratory studies later in the year.

A survey on the use of toughness tests in this field was reported. An exploratory study in several laboratories will be made using a constant-rate-of-loading apparatus on four types of plain films and three laminated films.

Work is continuing on the development of a seal strength test for flexible barriers, an impact test, tearing tests, and a stiffness test. Studies are continuing on water-vapor and gas transmission through flexible barriers.

Thermal Insulating Materials

With general activity being reported across the entire field of thermal insulating materials, perhaps the most significant was in the measurement of such basic properties as vapor transmission and thermal conductivity as reported at the meeting of Committee C-16 on Thermal Insulating Materials held during ASTM Committee Week in Cincinnati the week of January 27. Revisions were considered in the present methods of tests for water vapor transmission of materials used in building construction (C 355) which will make this method more adaptable for general usage and, particularly, to meet the needs of the plastics industry. The responsible subcommittee also took an important step in accepting a list of metric units of permeance and permeability for conversion of the present terms. These units coincide with those agreed upon by the Danish National Institute of Building Research, the international organization concerned with building research studies and documentation.

The need for a second test method to measure thermal conductivity was reflected in the acceptance of a proposed heat flow test method by the responsible subcommittee preliminary to presentation to Committee C-16. This subcommittee is also studying the line heat source type of apparatus. In connection with this phase of committee activity, a joint meeting of the officers of Committees C-16 and D-20 was held which resulted in a much better understanding of the interests of the two committees. Plans were made for closer coordination in the development of test methods and specifications covering thermal insulating materials involving the use of plastics.

A proposed specification for expanded polystyrene block-type insulation was approved, subject to letter ballot of the committee. Test methods are being developed for water absorption, impact strength, and hardness measured by penetrometer apparatus, for block and pipe insulation.

The Subcommittee on Blanket Insulation is concentrating its efforts on the development of test methods and specifications for mineral thermal wool insulation for buildings. A proposed recommended practice for determining outside diameter of thermal-pipe insulation was accepted, subject to committee letter ballot. An additional recommended practice is being developed covering the fit of matching segmented pairs of thermal insulation for pipe, together with proposed methods of test for trueness and squareness of block insulation.

Petroleum Products and Lubricants

Over 500 persons attended the February 5–10 meeting of Committee D-2 held in Philadelphia at the Benjamin Franklin Hotel, shattering all previous attendance records.

Symposium on Hydraulic Fluids

The problem of detecting and measuring particle contamination of hydraulic fluids was discussed at an informal symposium held on Monday afternoon, February 6. In aerospace applications, hydraulic fluids must be exceptionally free of dirt, so much so that ideas of what constitutes "clean" are being revised. Speakers included J. H. Rushton, Purdue University; O. A. Ullrich, Battelle Memorial Inst.; and E. F. Casey, Rocketdyne, Division of North American Aviation. A paper from Stanford Research Inst. was read.

Symposium on Motor Gasoline

The Society will publish the complete proceedings of the three-session symposium on motor gasoline held on February 7. About 275 persons representing consumer, petroleum, automotive, and government groups listened to discussions of the effect of current research on future gasoline specifications. Ten papers on combustion, additives,

Society Officers Nominated

NOMINEES FOR ASTM president, vice-president, and six directors were selected by the Nominating Committee at its meeting in Cincinnati, February 1, 1961. The committee announces the following nominations:

For president (1 year):

Miles N. Clair, president, The Thompson & Lichtner Co., Inc., Brookline, Mass.

For vice-president (2 years):

Alfred C. Webber, assistant laboratory director, Polychemicals Dept., Research and Development Div., E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

For director (3 years):

Ardrey M. Bounds, chief metallurgist, Superior Tube Co., Norristown, Pa.

Albert G. H. Dietz, professor of building engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Bruce W. Gonser, technical director, Battelle Memorial Inst., Columbus, Ohio.

W. A. Kirklin, manager, Analytical Div., Research Center, Hercules Powder Co., Wilmington, Del.

Gordon M. Kline, chief, Division of Organic and Fibrous Materials, National Bureau of Standards, Washington, D. C.

J. B. Rather, Jr., administrative director, Socony Mobil Oil Co., Inc., Research Dept., Brooklyn, N. Y.

Society By-laws provide that "Further nominations, signed by at least 25 members, may be submitted to the Executive Secretary in writing by May 25, and a nomination so made, if accepted by the member nominated, shall be placed on the official ballot." The ballot will be issued to members between May 25 and June 1.

and future automobiles were featured. H. M. Smith, chairman of Committee D-2; D. P. Barnard IV, past-president of SAE; and J. B. Rather, Jr., chairman of the symposium program committee, presided.

Reorganization

Reorganization of some of Committee D-2 lubrication activities was started. Technical Committee B will concern itself in the future with the field of automotive lubrication. A new committee on industrial oils will be formed to deal with this phase of Technical Committee B work and some of the other industrial oil activity in Committee D-2.

Standards on Petroleum

The painstaking work during the past year of maintaining and enlarging the collection of ASTM standard methods of test on petroleum resulted in a number of recommendations for consideration by Committee D-2 and the Society. New tentative methods to be considered include:

Roll Stability of Lubricating Grease.
Volatility of Liquefied Petroleum Gas.
Copper Corrosion by Liquefied Petroleum Gas.
Peroxide Number of Petroleum Wax.
Odor of Petroleum Wax.
20-deg Specular Gloss of Waxed Paper.
Amyl Nitrate in Diesel Fuels.
Naphthalene Hydrocarbons in Aviation Turbine Fuels.

Revisions of 22 existing methods of test will be considered, including revisions in the specifications for burner fuel oils (D 396) and the specifications for aviation turbine fuels (D 1655). Two new tentative specifications will also be considered: (1) for commercial hexanes, and (2) for liquefied petroleum gases.

Committee D-2 Dinner

Harold M. Smith, U. S. Bureau of Mines, Bartlesville, Okla., was selected to be the guest of honor at the Committee D-2 Dinner on June 27, 1961, in recognition of his contribution to the work of the committee.

Industrial Aromatic Hydrocarbons

At a meeting of Committee D-16 in Philadelphia on February 8, 9, and 10, it was reported that methods covering phenylethylene or styrene that have had considerable background of use in industry are being standardized. The following four methods, for which precision and accuracy data are being developed, will shortly be published: methods of test for aldehydes in styrene monomer, solubility of styrene polymers, polymer content of styrene monomers, and inhibitor (4-*tert* butylcatechol) in styrene monomers. Methods for chlorine, sulfur, and peroxide content in styrene are also being developed. Revision of the methods for calculations of volume and weight for aromatic hydrocarbons (D 1555) are being contemplated which will completely alter the format. It is proposed that the "weight, in pounds per U. S. gallon in air," be deleted, since these tables do not apply to ordinary production of aromatic hydrocarbons. The tables are to be expanded to include styrene and mixed xylenes and to include information relating to observed density at 20 C. Since the proposed tables will refer to density, new hydrometers for density measurement of aromatic hydrocarbons will have to be developed. The density tables will permit easy conversion of volume to weight of the aromatic hydrocarbons in any system so as to set up an international standard way of presenting these data.

A proposal that Method D 891, covering specific gravity of industrial aromatic hydrocarbons, be revised to become a method for determining the density of aromatic hydrocarbons was presented as part of the move to standardize weight-volume measurements in terms of density, thus tying in with the proposals for Method D 1555.

Methods covering the cloud point of phenol and color of refined phenol are being developed. Methods for sulfur, solidification point, and sampling of naphthalene are also being developed. Upon the establishment of a filter and optical cell for the photometric procedure for measuring acid wash color of refined naphthalene, an interlaboratory study will be initiated. Methods for determining the water solubility and permanganate number of refined pyridine are being collaboratively tested. A method for oil content of refined pyridine is also being investigated.

Chemical-Resistant Mortars

The expansion of activity beyond that of its present scope was one of the primary topics of discussion at the meeting of Committee C-3 on Chemical-Resistant Mortars held in Washington, D. C., February 23 and 24. The proposed expansion will include the development of standards for hot-melt compounds, adhesives, putties, monolithic surfacing compounds, sheet liners, and self-supporting structures, as used primarily for protection against corrosive chemicals. A proposed change in title and scope was approved for presentation to the Board of Directors. It was realized that this additional coverage will require coordination with other ASTM technical committees.

A proposed specification for chemically setting silicate-type chemical-resistant mortars was accepted, subject to committee letter ballot. This specification includes binders, which may be aqueous solutions of sodium silicate, potassium silicate, and silica salts. The fillers may be silica, quartz, ganister, and other material insoluble in common mineral acids except hydrofluoric.

Determination of modulus of elasticity using the sonic method is the subject of current round-robin tests. Results to date indicate agreement on all materials used, except for silicates. A draft of a method will be prepared, possibly being restricted to resin-type mortars. Other round-robin tests are planned to collect data on a proposed brittle ring tension test. Action was taken to change the conditioning requirements in the Method of Test for Tensile Strength of Resin-Type Chemical-Resistant Mortars (C 307) to conform with the standard conditioning temperature of 23 ± 2.2 C.

Soaps and Other Detergents

After a delay of several years Committee D-12 on Soaps and Other Detergents now feels that the time is ripe for the preparation of specifications for synthetic detergents. At its meeting in New York City on March 6 and 7 Subcommittee S-2 on Specifications for Soaps and Synthetic Detergents formed a task group which immediately set to work on a specification for a "built" all-purpose detergent. Subcommittee S-2 also feels the need for a specification for hard, soft, or sea-water toilet soap, and a task group was appointed to prepare a specification for such a so-called "combination bar."

Nearing completion in Committee D-12 are specifications for sodium triphosphate and scouring powders.

Electron Tubes and Semiconductors

Two hundred electronic materials specialists, representing 93 electronics and electronics material supply firms, as well as representatives of academic and government organizations, were in attendance at the meeting of Committee F-1 on Materials for Electron Tubes and Semiconductor Devices in Washington, D. C., the week of February 13.

Highlighting the meeting were two symposia sponsored by Subcommittee X on Contaminant Control. One symposium thoroughly aired the problems of handling beryllium oxide ceramics, which have assumed an important position in the electronics industry because of their fortunate combination of low electrical and high thermal conductivity.

The second symposium heard representatives of hydrogen peroxide producers discuss purity and control problems. Hydrogen peroxide is widely used in the tube and transistor industry in processing and surface cleaning.

Subcommittee X also has under active consideration techniques for

measuring and controlling air-borne contaminants, the cleanliness of surfaces, and the control of process liquids. A new task group is considering the problems involved in the control of getters and other gas adsorbers.

The Subcommittee on Cathode Materials has reworked the specification on the measurement of interface impedance (F 300) and has compiled basic information on the techniques of measurement of tube-component temperatures. The Subcommittee on Strip is currently concerned with defining the character of the surface as well as the strip gas content. The Wire Subcommittee had a busy agenda, with principal emphasis on techniques for measuring wire sizes and the control of grid side-rod materials.

The Metal-Nonmetal Seal Subcommittee concerns itself with the component metals, ceramics, and glass, as well as their combinations. A new activity is the assessment of techniques to measure the leakproof nature of subassemblies and devices—both tubes and semiconductors.

The Semiconductor Subcommittee has under consideration the problems of oxygen in silicon, standardizing of techniques for the measurements of mobility, resistivity, lifetime, crystal perfection, and conductivity type. Much concern was evidenced in establishing methods acceptable to purchasers and sellers to evaluate the thickness, surface finish, and electrical properties of epitaxial films.

Cellulose and Its Derivatives

A MEETING OF Committee D-23 on Cellulose and Cellulose Derivatives on February 22 in New York was attended by members of the TAPPI Chemical Methods Committee. Additions to the methods for testing cellulose acetate butyrate (D 817) were presented. These include heat stability, hydroxyl content, primary hydroxyl content, sulfur or sulfate content, intrinsic viscosity, color, and haze. The title is also being changed to read "Methods of Testing Cellulose Acetate Propionate and Cellulose Acetate Butyrate." Revisions are also being proposed for the methods of testing cellulose acetate (D 871). These will include the addition of methods for heat stability, hydroxyl content, primary hydroxyl content, sulfur or sulfate content, intrinsic viscosity, color, and haze.

A new method has been completed for determining the degree of etherification for pure grades of sodium carboxymethycellulose (CMC) in nonaqueous media using the perchloric acid with dioxane technique.

A new method for determining sodium glycolate by the colorimetric chromatographic procedures is being developed. The viscosity method is being revised to include highly refined pure sodium CMC. The present method is only suitable for low-viscosity determination. Interlaboratory data are being circulated in the committee from the method for degree of substitution of sodium CMC.

The committee is considering a project covering hydroxy-alkyl-cellulose test methods. All those interested in this material are urged to get in touch with R. W. Swinehart, Cellulose Products Div., Dow Chemical Co., Midland, Mich.

Manufactured Masonry Units

Drain tile was given extensive study during a three-day meeting of the Subcommittee on Drain Tile which preceded the meetings of Committee C-15 on Manufactured Masonry Units held during ASTM Committee Week in Cincinnati. Part of the three-day meeting was in the form of an "open house" for all those interested in clay drain tile, particularly consumers. A number of revisions were approved in the specification for clay drain tile (C 4), with one of the problems being "hairline" cracks. Agreement was reached on the desirability of a separate specification for perforated clay drain tile. A draft will be prepared and circulated for review.

A report on the work in Committee C-12 on Mortars for Unit Masonry on the development of a test to determine the amount of efflorescent material in mortars was given at the meeting of the Subcommittee on Clay Brick and Tile. The members of Committee C-15 were unanimous in urging Committee C-12 to accelerate further investigation on this subject in order that suitable test methods might be developed and appropriate limits on efflorescence included in specifications.

More realistic limits on permissible chippage of face brick will be considered by a task group based upon an extensive survey that has been made. A progress report was also given on accelerated freezing-and-thawing tests on brick, which is being compared with the present standard test.

A final draft of a proposed specification for ceramic tower packings will be circulated to representative producers and consumers for comments, preliminary to submittal to Committee C-15 for its approval.

New Developments in Industrial Water Testing

COMPLETION OF the research project on investigation of vaporous carryover of boiler water salts was announced at the meetings of Committee D-19 on Industrial Water at Pittsburgh, Pa., January 24–27. A detailed report on this project will be given in a paper at the Symposium on Impurities of Steam at the 1961 Annual Meeting.

New methods of testing industrial water that were approved for submittal to the Society include open-channel flow measurement by Parshall flume, chloride ion in high-purity industrial water by flame photometry, turbidity, hexane-extractable matter, and beta particle radioactivity.

Specifications for heavy water for reactor use were discussed and will be circulated in the task group for further consideration. Test methods are under development for the constituents and properties prescribed in the specifications.

Officers of Committee D-19 on Industrial Water photographed at their meeting, January 25-27, 1961, at the Penn-Sheraton Hotel in Pittsburgh, Pa. ***Standing, left to right:*** **A. C. Muller (standards advisor), assistant division chemist, Consolidated Edison Co. of New York, Inc.; and F. E. Clarke (vice chairman), head, chemical engineering, U. S. Naval Engineering Experiment Station.** ***Seated, left to right:*** **Orrin M. Elliott (secretary), water treatment engineer, Sun Oil Co.; Max Hecht (chairman); and F. R. Owens (vice-chairman), chairman of the board, Cyrus William Rice and Co., Inc.**

New SBR Rubber Announced

NUMBER 1610 has been assigned by Committee D-11 on Rubber and Rubber-Like Materials to a new styrene-butadiene rubber (SBR) recently brought on the market. Assignment of this number was made by Subcommittee XIII on Synthetic Elastomers, B. S. Garvey, chairman, in accordance with the Recommended Practice for Description of Styrene-Butadiene Rubbers (SBR) and Butadiene Rubbers (BR) (D 1419–60a T). A description of the new SBR rubber is as follows:

Number Assigned	1610
Date assigned	1/9/61
Requested by	Goodrich-Gulf Chemicals, Inc.
Distinctive feature	ISAF black, softener oil 10 PHR
Close previous number, if any	1608
Type	1600
Nominal temperature, deg Fahr	43
Activator	FRA
Shortstop	ND
Antioxidant	ST
Catalyst	OHP
Emulsifier	RA
Nominal bound styrene, per cent	23.5
Nominal conversion, per cent	60
Nominal Mooney viscosity, ML 1 + 4 (212 F), compound	57
Coagulation	Acid
Carbon black:	
Type	ISAF
PHR	52
Oil:	
Type	HI-AR
PHR	10
Finishing	Normal

NOTE.—Abbreviations and symbols are defined as follows: FRA = free radical type, that is, iron pyrophosphate, peroxamine sulfoxylate. ND = nondiscoloring. ST = staining. OHP = organic hydroperoxide. RA = rosin acid. ISAF = intermediate super abrasion furnace. HI-AR = highly aromatic.

Casein and Similar Protein Materials

AT THE MEETING of Committee D-25 on February 24 in New York, three interlaboratory test series conducted over the past two years for the determination of Brookfield viscosity of casein solutions were reviewed. These data are being presented to the committee in order to determine whether a standard method of measuring the viscosity of casein solutions can be published in the near future. A study of cooperative tests for developing an adhesive strength test for adhesives used in pigmented coatings was also presented.

Other tests being studied include those for dirt content, odor, insoluble alkali requirement, and foaming tendency of casein and soy protein.

ACTIONS ON STANDARDS

The Administrative Committee on Standards is empowered to pass on proposed new tentatives and revisions of existing tentatives, tentative revisions of standards, and the withdrawal of tentatives and standards offered between Annual Meetings of the Society. On the dates indicated the Standards Committee took the following actions. Anyone interested in securing copies of the standards should write to Headquarters regarding their availability.

Steel

Tentative Specification for Low-Carbon Steel Externally and Internally Threaded Standard Fasteners (A 307 – 58 T) (Accepted March 1, 1961).

Revision.—Requirements, identified as grade B, have been added for bolts requiring low phosphorus and sulfur, and the present requirements have been identified as grade A.

Tentative Specification for Galvanized Steel Transmission Tower Bolts and Nuts (A 394 – 55 T) (Accepted March 1, 1961).

Revision.—The specification has been brought in line with current practice as to the bolts and nuts that are used in the construction of galvanized steel transmission towers.

Non-ferrous Metals and Alloys

Tentative Specification for Seamless and Welded Unalloyed Titanium Welding Fittings (B 363 – 61 T).

New Tentative.—These specifications cover wrought welding fittings intended for general corrosion-resisting and elevated-temperature services, factory made from three grades of unalloyed titanium. They do not apply to cast welding fittings.

TENTATIVE SPECIFICATION FOR:

Tantalum Ingots and Flat Mill Products (B 364 – 61 T) (Accepted March 1, 1961).

Tantalum Rod and Wire (B 365 – 61 T) (Accepted March 1, 1961).

New Tentatives.—An urgent need had been expressed for these specifications. The grades of unalloyed tantalum covered are powder metallurgy, arc cast, and electron-beam cast. Specification B 354 covers ingot, bar, plate, sheet, strip, and foil, and Specification B 365 covers rod and wire.

Thermal Insulating Materials

Tentative Method of Test for Corrosion of Steel in Contact with Wet Thermal Insulating Cement (C 464 – 61 T) (Accepted March 1, 1961).

New Tentative.—A procedure is provided for determining the likelihood of corrosion occurring on a steel surface at ambient temperature during the application and initial drying of thermal insulating cements. It is a qualitative rather than a quantitative test and can be used on other types of test surfaces.

Rubber

Tentative Method of Tension Testing of Vulcanized Rubber (D 412 – 51 T) (Accepted March 1, 1961).

Revision.—The use of strain gages as an additional recording device for tension testing has been provided for.

Tentative Methods for Chemical Analysis of Natural Rubber (D 1278 – 58 T) (Accepted March 1, 1961).

Revision.—The procedures for determination of ash, copper, manganese, iron, and rubber hydrocarbon content have been amplified and clarified.

Tentative Recommended Practice for Inscription of Types of Styrene-Butadiene Rubber (D 1419 – 60 T) (Accepted March 1, 1961).

Revision.—A new SBR polymer, Type 1570, has been added.

This is essentially a confirmatory action covering the addition of this new polymer in the last printing of the standard.

Standard Methods of Test for Compression Set of Vulcanized Rubber (D 395 – 55) (Accepted March 1, 1961).

Tentative Revision.—Provisions are made for a fully molded specimen in addition to the died-out and plied-up specimens.

Electrical Insulating Liquids

Tentative Method of Test for Gas Content (Non-Acidic) of Insulating Liquids by Displacement with Carbon Dioxide (D 1827 – 61 T) (Accepted Feb. 15, 1961).

New Tentative.—Electrical insulating liquids in many applications, such as in capacitors and certain types of cable, require low gas content. This test is intended for determining the gas content of electrical insulating liquids with a viscosity of 1000 sec Saybolt Universal or less at 100 C. It is used as a factory control test and as a control and functional test in installation and maintenance work by utilities.

Gaseous Fuels

Tentative Methods of Test for Calorific Value of Gases in the Natural Gas Range by the Continuous-Recording Calorimeter (D 1826 – 61 T) (Accepted Feb. 15, 1961).

New Tentative.—This test is intended for use when a continuous-recording calorimeter is used to determine the total calorific value of fuel gas produced or sold in the natural gas range of 900 to 1200 Btu per standard cubic foot.

Tentative Method for Analysis of Carbureted Water Gas by the Mass Spectrometer (D 1302 – 53 T) (Accepted Feb. 15, 1961).

Revision.—General revisions and refinements have been made in the method.

Plastics

TENTATIVE METHOD OF TEST FOR:

Apparent Viscosity of Plastisols and Organosols at Low Shear Rates (Castor-Severs Method) (D 1823 – 61 T) (Accepted March 1, 1961).

Apparent Viscosity of Plastisols and Organosols at High Shear Rates (Brookfield Viscometer Method) (Accepted March 1, 1961).

New Tentatives.—Methods are provided for the measurement of plastisol and organosol viscosity at low shear rates by means of the Brookfield viscometer, and at high shear rates by means of the Castor-Severs viscometer.

Standard Specification for Ethyl Cellulose Molding and Extrusion Compounds (D 787 – 55) (Accepted March 1, 1961).

Revision and Reversion to Tentative.—The specification has been expanded to cover eleven grades of ethyl cellulose molding and extrusion compounds; previously it had covered six grades.

NBS Offers Calibration Service for Thermocouples and Platinum Resistance Thermometers

THERE IS A GROWING need in all branches of science and technology for temperature measurements of increased accuracy and precision. Platinum resistance thermometers, which can be used over a wide range of temperatures, help to fill this need. The calibration services of the National Bureau of Standards contribute to the accuracy of temperature measurements made with these instruments. Although there are many types of resistance thermometers, using a variety of materials, the Bureau specifies that only thermometers having a four-lead resistor of very pure platinum, hermetically sealed in a protecting tube, be submitted for calibration.

Thermocouples are calibrated over the temperature range of −190 to 1100 C. Depending on the material submitted, the degree of accuracy required, and the temperature range covered, the thermocouples are compared with either standard resistance thermometers or standard platinum thermocouples, or calibrated at fixed points on the International Temperature Scale. Thermocouple materials—wires of various composition—are also calibrated, as are potentiometers. Standard samples of various metals are prepared as freezing-point standards, to aid other laboratories involved in thermocouple calibration.

ASTM MEETINGS

This gives the latest information available at ASTM Headquarters. Direct mail notices of all district and committee meetings customarily distributed by the officers of the respective groups should be the final source of information on dates and location of meetings. This schedule does not attempt to list all meetings of smaller sections and subgroups.

Date	Group	Place
May 6	New England District	Orono, Me. (University of Maine)
June 4–9	Committee E-14 on Mass Spectrometry	Chicago, Ill.
June 9	Committee E-19 on Gas Chromatography	Chicago, Ill. (Sherman)
June 13	(Tentative) Northwest District (Joint with Am. Soc. Mechanical Engineers and Am. Soc. Metals)	Richland, Wash.
June 25–30	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**
	1962	
Feb. 5–9	**Committee Week**	**Dallas, Tex. (Statler-Hilton)**
June 24–29	**Annual Meeting**	**New York, N. Y. (Statler-Hilton)**
Sept. 30–Oct. 5	**Pacific Area Meeting**	**Los Angeles, Calif. (Statler-Hilton)**
	1963	
Feb. 4–8	**Committee Week**	**Montreal, Canada (Queen Elizabeth)**
June 23–28	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

ASTM National Meetings

Five-Year Preview

	Committee Week	Annual Meeting	Pacific Area Meeting
1962	February 5–9, Statler Hilton Hotel, Dallas, Tex.	June 24–29, Statler Hotel, New York, N. Y. (Apparatus Exhibit)	Sept. 30–Oct. 5, Statler Hilton Hotel, Los Angeles, Calif. (Apparatus Exhibit)
1963	February 4–8, Queen Elizabeth Hotel, Montreal, Canada	June 23–28, Chalfonte-Haddon Hall, Atlantic City, N. J.	No meeting
1964	February 3–7, Sheraton Hotel, Philadelphia, Pa.	June 21–26, Conrad Hilton, Chicago, Ill. (Apparatus Exhibit)	No meeting
1965	February 8–12, Statler Hotel, Cleveland, Ohio	June 13–18, Purdue University, Lafayette, Ind.	Oct. 31–Nov. 5, Olympic Hotel, Seattle, Wash.
1966	Jan. 30–Feb. 4, Shoreham and Sheraton-Park, Washington, D. C.	June 26–July 1, Chalfonte-Haddon Hall, Atlantic City, N. J. (Apparatus Exhibit)	No meeting

MATERIALS SCIENCES

Fourth International Symposium on the Chemistry of Cement

(from *National Bureau of Standards Technical News*, Vol. 45, No. 2, February, 1961)

To accelerate exchange of information and thus to establish closer coordination on research in cement, the National Bureau of Standards and the Portland Cement Assn. jointly sponsored the Fourth International Symposium on the Chemistry of Cement.[1] The symposium was held October 3–7 at the National Bureau of Standards in Washington. Approximately 300 scientists from the United States and more than 30 other countries attended the sessions. The last international symposium on cement was held in London in 1952.

Reviewing the progress in the field of cement research since the last Symposium, F. M. Lea, director of the Building Research Station, United Kingdom, spoke on "Cement Research, Retrospect and Prospect." He pointed out that perhaps the most notable feature of this symposium in comparison with the 1952 meeting is the increased proportion of papers bearing on the hydration of cements. Recent research has led to a fair picture of the chemical and physical nature of set cement, but much remains to be learned about the kinetics of the initial reactions and the mechanism by which the initial framework of setting cement is developed.

After the opening general addresses, technical sessions devoted to specific aspects of cement chemistry were held. The topics were: Chemistry of Clinker, Chemistry of Hydration of Cement Compounds, Chemistry of Hydration of Portland Cement, Properties of Cement Paste and Concrete, Destructive Processes in Concrete, and Special Cements. Within each session two or more principal review papers were presented in condensed form. These were followed by shorter papers dealing with specific investigations, which, in turn, were followed by both prepared and informal discussions.

[1] The Proceedings of the Symposium will be published in late 1961 by the National Bureau of Standards.

The Russell Effect

(from *Metal Industry*, Vol. 97, No. 1, 29 July 1960)

SLOW BUT at any rate sure progress continues to be made in the task of elucidating the Russell effect—the blackening of certain photographic emulsions by freshly fractured or abraded surfaces; an effect first studied by Russell in 1897. Much more recently, the Russell effect has been shown to be due to the formation of hydrogen peroxide on the freshly exposed metal surfaces, and, more recently still, that the formation of hydrogen peroxide is initiated, in the presence of water vapour and oxygen, by the emission of low-energy electrons, the so-called exo-

NEW ASTM PUBLICATIONS

Manual on Industrial Water and Industrial Waste Water

STP 148-E, 686 pp.; cloth cover; price $11.00, to members $8.80.

THE SECOND printing of the second edition (1959) of the Manual on Industrial Water and Industrial Waste Water includes new methods for evaluating operating performance of cation-exchange materials and for determining phenolic compounds in industrial water, nine revised methods, and revised definitions relating to industrial water and industrial waste water. The remainder of the material in this printing is identical with the 1959 printing of the second edition. That printing was recently named by *Library Journal* one of the 100 best technical books of 1960 (see p. 290).

The manual provides valuable information on the uses of industrial water and the problems of sampling and analysis in the ten chapters comprising Part I. Methods for all important determinations on industrial water, including methods for sampling, are given in Part II. The manual, therefore, is useful to all concerned with industrial water, including executives, plant managers, designers, administrators, technologists, and chemists.

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Errata in Yellow Stickers in 1960 Supplement to Book of ASTM Standards, Part 2

p. 709 (B 23 – 49)

The yellow stickers accompanying this supplement contain two unidentified tables: (1) Table I.—Chemical Composition; and (2) Table of Composition and Physical Properties of White Metal Bearing Alloys. These are revisions of the Standard Specifications for White Metal Bearing Alloys (ASTM Designation: B 23 – 59) which appear in the 1958 Book of ASTM Standards, Part 2, p. 709; the yellow stickers should be inserted therein. The latter table is a replacement for the one appearing in the Appendix to Specifications B 23.

p. 1165 (B 230 – 58)

Change the last sentence in the yellow sticker for B 230 – 58 to read as follows:

"Such tests shall show the tensile strength to be not less than 11,000 psi for electrical butt-welded joints, and not less than 21,000 psi for cold pressure-welded joints."

electrons. Further studies indicated that in the case of metals these exo-electrons are emitted from crystal imperfections in the freshly formed or distorted oxide layer. Using a high-resolution stripping photographic emulsion, applied directly to the metal surface, investigators at the British Iron and Steel Research Association have now succeeded in tracing back these exo-electrons nearer to the sources from which they originate. High-purity zinc single crystal rods were electropolished, cleaned, statically strained, and then at once coated with the stripping emulsion, which was then left on the surface for about 1 hr. Subsequent examination of the emulsion revealed closely spaced parallel black lines, corresponding exactly to slip-lines on the crystal surface. Some of these lines were continuous, others were more or less discontinuous, while others, again, were resolvable into rows of individual spots. These differences are related to the magnitude of the slip displacement, the individual spots being analogous to dislocation etch pits. The Russell effect, and probably exo-electron emission in plastically deformed metals, thus originate from slip bands on the surface, the centers of emission probably being the points where dislocations terminate at the surface of the crystal. It is to be hoped that further research on the Russell effect and exo-electrons will succeed in throwing sufficient light on the subject to enable, in turn, the use of these phenomena to throw some light on the nature and behaviour of imperfections and of freshly exposed metal surfaces in slip bands.

Carbon-14 Half-life Redetermined

The National Bureau of Standards announced recently that a more accurate value for the half-life of carbon-14—important in geological and archeological dating—has been obtained. The new value is 5760 years, with an over-all probable error of 1 per cent. The new value is about 4 per cent greater than the previously adopted value. Measurements were made on high-specific activity carbon dioxide, using gas counters in the Geiger and proportional regions. Measurements had previously been made on the same material to determine the isotopic abundance of carbon-14, which was found to be about 44 atoms per cent. The new value for half-life will enable much better dating of fossils and other archeological specimens.

DISTRICT ACTIVITIES

CENTRAL NEW YORK

The Central New York District of ASTM held a joint meeting with the Mohawk Valley Chapter of the American Society for Metals at the Beeches in Rome, N. Y., on Monday evening, March 6, 1961. The meeting was chaired jointly by Stephen Thurber, chairman of the ASM Chapter, and George H. Harnden, chairman of the ASTM Central New York District.

ASTM Student Award Certificates were distributed to 15 members from Union College, Syracuse University, and Mohawk Valley Technical Inst.

T. A. Marshall, Jr., executive secretary of ASTM, spoke briefly on "Progress at ASTM," and Stephen Thurber, chairman of ASM's Mohawk Valley Chapter, presented a brief picture of "What's New at ASM."

The address of the evening was an illustrated lecture by John C. Fisher, physicist at the General Electric Research Laboratory, and 1959 Gillett Memorial Lecturer, on "World Effort in Materials Research." Dr. Fisher discussed the progress being made in various areas with particular emphasis on plastic deformation and recent work being done in that field.

SOUTHWEST

A. Allan Bates, president of ASTM, addressed a joint meeting of more than 50 members of ASTM's Southwest District and the New Orleans Chapter of the American Institute of Architects at the Fontainebleau Motor Hotel in New Orleans on Wednesday, March. 8.

Before making his address, Dr. Bates was presented with a certificate signed by Mayor de Lesseps S. Morrison designating him as an honorary citizen of the City of New Orleans.

Dr. Bates' talk was based on his recent visit to the Soviet Union and emphasized particularly the problems of design and construction of Soviet housing. He pointed out the tremendous industralization of the construction industry as a result of the decision to industrialize the USSR. This decision, coupled with loss of homes for many citizens during World War II, necessitated the construction of dwellings for more than one million residents, most of whom were moved from agriculture and rural living to industry and urban living.

The meeting was chaired by Murvan M. Maxwell, president of the New Orleans Chapter of the American Institute of Architects. Dr. Bates was introducted by Cecil M. Shilstone of the ASTM Southwest District Council. A lively question-and-answer session followed Dr. Bates' address.

Houston

Under the chairmanship of Briggs B. Manuel of Houston, Tex., the Southwest District held two meetings in Houston on Thursday, March 9.

At a luncheon meeting attended by 45 members and students, T. A. Marshall, Jr., executive secretary of ASTM, gave a brief address on the value of ASTM and technical society activity to the engineering profession. Dr. Bates presented student award memberships to students from the University of Houston and the William Marsh Rice University.

At a joint dinner meeting at the Ramada Inn in Houston, more than 100 members of the Houston Branch of the

Executive Secretary Marshall Distributes Student Award Certificates at Central New York District Meeting.

American Society of Civil Engineers and the Southwest District of ASTM heard Dr. Bates discuss American and Soviet construction materials and methods. Dr. Bates' address was based on his visit to the Soviet Union as chairman of an exchange delegation arranged by the U. S. Department of State with the Soviet Union to study construction methods.

Dallas

A small informal meeting was held at the Engineers Club in Dallas on Friday, March 10, with Cedric Willson, vice-chairman of the Southwest District, as host to President Bates and Executive Secretary Marshall. Plans were discussed for the formation of a North Texas District of ASTM and a joint meeting to be held on April 10 with the Fort Worth and Dallas branches of the American Society of Civil Engineers and the Texas Society of Professional Engineers.

Bartlesville

Dr. Bates was the principal speaker at a banquet jointly sponsored by the Southwest District of ASTM and the Oklahoma Section of the American Chemical Society on Saturday evening, March 11, at the Elks Club in Bartlesville, Okla. The banquet was the climax of the Tetra-sectional ACS Conference held earlier in the day in Bartlesville and was attended by 350 members and guests of the two societies, including their ladies.

Mr. Marshall was introduced by Mr. Harold M. Smith, chairman, Committee D-2; and Dr. Bates, who gave the principal address, was introduced by R. W. Thomas, vice-president, research and development, Phillips Petroleum Co.

At the conclusion of Dr. Bates' address, he and Mr. Marshall were presented with tie clasps and cuff link sets as souvenirs of the occasion.

SOUTHEAST

More than 50 members of the ASTM Southeast District and the Birmingham Chapter of the American Society for Metals met for dinner at the Gold Nugget Restaurant in Birmingham, Ala., on Tuesday, March 7, to hear a talk by A. Allan Bates, president of ASTM, on comparison of materials technologies in America and in the Soviet Union. The meeting was chaired by R. Wade Mooty, chairman of ASTM's Southeast District, assistant to manager, Tennessee Coal and Iron Div., U. S. Steel Corp., assisted by J. F. Ellis, of the American Cast Iron Pipe Co., chairman of ASM's Birmingham Chapter. Dr. Bates' talk was illustrated with pictures taken on his recent trip to the Soviet Union as senior member of an exchange team arranged under recent agreements to study construction methods in the Soviet Union and in the United States.

ACR NOTES — ADMINISTRATIVE COMMITTEE ON RESEARCH

Pure Substances and Measurement

By EDWARD WICHERS[1]

Ed. Note.—**This guest column by Edward Wichers bears directly on the subject of the Symposium on Major Effects of Minor Constituents on the Properties of Materials sponsored by the Division of Materials Sciences and scheduled for Monday, June 26, at the 64th Annual Meeting.**

In recent years much progress has been made in the means of determining the purity of substances. Entirely new techniques have been devised, such as those of activation analysis, isotopic dilution, gas chromotography, mass spectrometry, and absorption spectrometry. Further, older methods of chemical and spectrochemical analysis have been refined and diversified; and physical measurements sensitive to small changes in composition have been sophisticated. All of these advances, if not quite keeping pace with increased demands, have certainly provided many new and sharper tools for getting more accurate and more detailed knowledge about purity.

Absolutely Pure

To prepare for the advantages to be gained from new and improved analytical and testing techniques in research on basic materials, it is well to examine some of the loose concepts and definitions we have grown used to. First of these is the idea that it is possible to think of a pure substance in absolute terms. Expressions such as "absolutely pure" and "completely free of impurities" are read and heard often, surprisingly often when a moment's reflection shows clearly that absolute purity is experimentally meaningless. Nearly all investigations of substances deal with quantities large enough to see and handle. Such quantities are composed of atomic or molecular entities ranging in number from a hundred billion billions upwards. Obviously in dealing with such a large population, we can be sure of the presence of undesired substances in considerable number and variety, even though we cannot identify them and count or measure them. A substance known to contain no more than 1 ppb of total impurities would command a good deal of respect in chemical circles, but a gram of water, for example, of this purity, would still contain of the order of a million million foreign molecules or ions. Among these alien species we should undoubtedly find, if we knew how to do it, every one of the chemical elements. Clearly, the purity of substances is a relative, rather than an absolute, matter. One substance may be purer than another and a given preparation of that substance as pure as can be achieved at a given moment, but in either case the purity attained may be surpassed tomorrow. In fact, no small part of the total progress of chemistry has dealt with this continuous improvement in our ability to purify substances.

Almost Absolutely Pure

In a moment we will discuss ways of setting mileposts to mark this progress, but first let us note the attempts we are all familiar with to define degrees of purity in descriptive terms. When the claim of "absolute purity" is not made, we are still likely to see superlatives such as "highest purity" or "extremely pure." These are not much more meaningful unless a great deal of auxiliary information is provided. Even more dangerous are the adjectives that seek to borrow authority from a particular process of purification or method of examination. The oldest such description is "chemically pure." Nobody has ever been able to learn just what this phrase means in quantitative terms, but it seems to have satisfied a lot of people, judging by the frequency with which one finds it in a publication as the only description of the purity of the substance used in the recorded research. That it also has caused many disappointments is clear by the derisive parodies on the initials "C.P." familiar to every chemist. A more recent and now more impressive term is "spectroscopically pure." This seems to have satisfied many readers, provided they are unfamiliar with the wide ranges of sensitivity and of accuracy that characterize the spectrographic determination of impurities. "Triply distilled"

[1] Associate Director, National Bureau of Standards.

and "electrolytically refined" have carried a lot of weight and influenced a lot of unquestioning folk. Today's magic phrase, even more impressive but not much more informative, is "zone refined."

Apart from their inherently qualitative character, modifying adjectives may fail to distinguish degrees of purity because of the connotations resulting from different ways in which substances are used. For example, "pure water" has a reasonably definite meaning if the water is for drinking. So does "pure water" if the intended use is to study the conductivity of dilute solutions. However, in terms of over-all purity these two kinds of water may differ a thousandfold or more. While the public water supply is not "pure" for conductivity measurements, conductivity water would be "impure" for drinking if it should by accident contain as little as one part by weight of a certain kind of impurity, in 100 million million parts of the water. This is about twice the permissible concentration of *Bacillus coli* in drinking water, according to customary public health requirements.

Another factor that causes the word "pure" to mean different things to different people is the relative difficulty of purification of different kinds of substances. It is possible, for example, with very simple equipment and in a very short time, to free mercury of other metals to a limit of 1 ppb or better. However, years of very painstaking effort have gone into preparing iron whose impurity content is at least ten thousandfold greater. A biochemist would be very pleased with a "pure' protein that in terms of over-all purity would be very inferior to many organic substances used in research or even in the synthetic fiber industry.

Just Plain Pure

Let us concede that there are some legitimate uses for the unadorned word "pure." One of these we have already mentioned—the situation in which the use connotation sets the proper bounds to the meaning. Another reasonable use of "pure" may occur when, in a course of progressive purification, a degree of purity is reached that is indistinguishable, by any available method, from one we would logically expect to be higher. However, neither situation represents a necessarily permanent, unchanging state of affairs.

Measures of Purity

Obviously, we shall always be better off when we define purity in numerical terms derived from appropriate measurements. To define the composition of a substance by measurements of tested reliability is the task that confronts those who hope to put modern research on materials on a sound basis. In the case of a one-component material, that is, a substance, the state of purity can be expressed numerically in two ways. One is in detail, by determining the concentration of each impurity present, or sometimes only of those impurities that are of interest in connection with a specific use of the substance. The latter variation of a detailed examination of purity is by far the more common. It is used, for example, in defining the quality of reagent chemicals, when the description states the actual or maximum content of each impurity thought to be of significance for the intended use of the substance. Such descriptions usually do not include all possible impurities. Similarly, transistor materials are likely to have their purity defined only with respect to those impurities that significantly affect the property of interest, that is, the semiconducting characteristics. This is satisfactory provided it is understood that the definition is limited and that the material so described is not necessarily equally pure with respect to all constituents.

In certain situations the matter of interest is not the nature or amount of individual impurities present in a substance, but rather its assay, or over-all purity. This is usually the case when the substance is to be used as a standard in the quantitative measurement of a chemical reaction or for the calibration of an instrument. Certain methods of measuring the content of impurities are nonspecific in their operation. This is true of most methods of evaluation based on the determination of a physical property, such as the measurement of the slope of a freezing curve of an organic compound or the measurement of the temperature coefficient of electrical resistivity of a metal. Neither of these methods depends on the chemical identity of the impurities in the substance. It measures instead the total atomic, ionic, or molecular concentration of all impurities of a general class. Such methods yield, by difference, the concentration of the major component of the system, that is, the degree of purity of the substance. Some methods of evaluating purity measure the major component directly. A notable example is the fire assay of gold, in which (ideally) all impurities in the metal are eliminated and the gold is recovered as a weighable residue. The result is expressed in a decimal fraction indicating the proportion of the element gold in the assayed material, for example, 0.9997. This very useful method of notation has become quite common for expressing the purity of many metals. It is being extended also to other substances when the interest is focused on the over-all purity of the substance rather than on the nature and concentration of its impurities.

We cannot allow ourselves to forget that the numerical expression of the purity of a substance is necessarily subject to the limitations of applicability, sensitivity, and accuracy that are inherent in all measuring techniques. In a detailed examination for specific impurities two matters are always to be considered. Was any impurity overlooked? Are the sensitivity and the accuracy of the specific methods adequately known? Very similar questions apply to methods used for determining impurities collectively. Are they in fact comprehensive? If not, what are the exceptions? Also, what are the limits of their accuracy? For the sake of reliable and complete communication of knowledge, it is important that the methods used for an evaluation of purity be stated in sufficient detail so that independent judgments of their suitability and reliability can be formed. The omission of such information is one of the chief faults of much published research in this field.

Finally, in dealing with a substance or material in the solid state, knowledge of gross or average composition frequently is not sufficient. The characteristics of such materials may depend strongly on microscopic and even submicroscopic inhomogeneities. Knowledge of these inhomogeneities or, in other words, of the distribution of impurities in the lattice, requires other techniques of observation and measurement than those mentioned here. They are for the most part new and only in the beginning of being understood. But, to be useful, they must submit to the same requirements of rigorous examination for reliability and of providing quantitative numerical information.

Symposium on Shock, Vibration, and Associated Environments

The 30th Symposium on Shock, Vibration, and Associated Environments, sponsored by the Office of the Director of Defense Research and Engineering, will be held in Detroit, Mich., Oct. 10–12, 1961. Areas to be covered are transportation and packaging and extreme operational environments. The sessions will be classified.

Tentative plans are also being made to hold a Shock and Vibration clinic. No prepared presentations are planned for this clinic, but there will be an opportunity for members of the audience to address questions either to the audience in general or to specific individuals.

The program is being arranged by the Centralizing Activity for Shock, Vibration, and Associated Environments and the Army Research Office. Inquiries should be addressed to Code 4021, U. S. Naval Research Laboratory, Washington 25, D. C.

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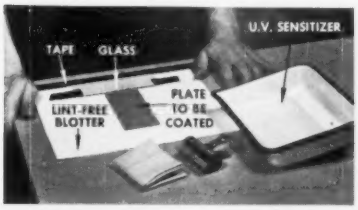
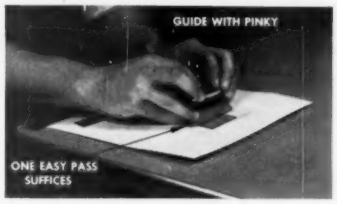
how you too can crack the 2500Å barrier...the competitive assault on salt...a reagent for alkyl halides

Ultraviolet swab

Even the sports pages are carrying help-wanted ads for infrared experts. Infrared is riding high. Let's not forget that at the other end of the visible spectrum the old ultraviolet is still there.

In order to stir up interest in the ultraviolet, we shall show you how to sensitize photographic plates below 2500A, the wavelength down to which all photographic emulsion responds but below which the gelatin of the emulsion starts to intercept the energy so that people don't bother as much as they should with the spectral lines and other interesting phenomena down there.





Working thus in the darkroom, you can extend the sensitivity of any of the numerous Kodak Spectroscopic Plates *down to 1000A, even those sensitive to 1.2μ in the infrared. To find out what sensitizations are available for extending, and how to make up* U-V sensitizer, *write Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.*

Cellmakers

Charles W. Warren

Paul A. Wilks, Jr.

Meet the founders of Connecticut Instrument Corporation, Wilton, Conn., POrter 2-5545. You can call them up and order any of a number of infrared accessories, including one they call a "C.I.C. Irtran-2 Fixed Thickness Absorption Cell" for $160. This fits directly into the standard cell slides of two of the more popular infrared spectrophotometers. Transmittance: better than 60% from 2 to 12μ. Clear aperture: 25 x 5mm. Nominal pathlengths available: 0.015mm to 1.0mm. Construction of mount: aluminum, with polytetrafluoroethylene spacer.

We are supposed to be angry with these boys. "Irtran-2" is our trademark, not theirs. They buy our Irtran-2 optical flats and build cells with them. Anybody who has the skill and the price can buy Irtran optical parts from Eastman Kodak Company, Special Products Division, Rochester 4, N. Y., and build with them.

Irtran-2 optical material is almost completely insoluble in water, which is more than can be said of the rock salt hitherto used for such cells. It can even be boiled in water and detergent to clean out contamination. It can be used in contact with reasonable concentrations of bases and most acids, including the hydrofluoric. Transmittance extends out several microns beyond that of the slightly water-soluble CaF_2. It resists thermal shock much better than BaF_2. It is about as strong as glass. It has a hardness of 354 Knoop.

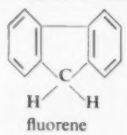
A cell made out of it does not change pathlength, as does one of NaCl.

Messrs. Warren and Wilks and associates are making and selling cells of Irtran material as fast as we can shoot the Irtran plates to them. We are so angry that we are giving them this advertising for free.

One week last summer

For many years we have been hiring chemistry graduate students for summer jobs. It gives them a chance to look us over and vice versa. Some of the biggest wheels in the corporation came that way. Others found three months of estival service to mammon sufficient for a lifetime and have become famous professors of chemistry. Still others have slipped through our fingers to become wheels in other companies. (You can't win them all.)

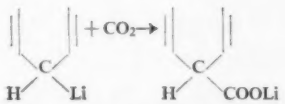
Methyl Fluorene - 9 - Carboxylate (Eastman 8164) represents a week's work last summer by one of these young men. The man he was hired to assist specializes in organometallic reactions. The mentor found a lithium reaction to give him in the April 1960 *Analytical Chemistry* on page 554. The summer man reacted lithium wire with bromobenzene to produce phenyllithium. He used this to replace one of the central hydrogens in



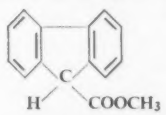
fluorene

by lithium.

Next,



On acidification, an H replaced the Li. He then esterified with methanol, with HCl as catalyst. His product,



was good enough to overcome the skepticism of our genial but skeptical chief control chemist.

Nobody patted him on the head for his accomplishment. All he accomplished was to make it unnecessary for other chemists who look up the *Anal. Chem.* reference to spend a week of their own time preparing the reagent that has been found to react with a wide variety of alkyl halides to yield sharp-melting derivatives. Since such reagents are few and far between, you may even wish to send for a procedural abstract. Or for an employment application form.

Or for Catalog No. 42, listing some 3800 Eastman Organic Chemicals we stock at Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

BOOKSHELF

Members who wish to be considered for reviewing books are invited to send in their names and the subjects in which they are interested. Due to customs and mailing considerations, requests from the United States only can be considered. Copies of these books are not available through ASTM; all inquiries concerning them should be addressed to the publisher.

Prophet of Progress

Selections from the Speeches of Charles F. Kettering, edited by T. A. Boyd; E. P. Dutton & Co., New York, N. Y. (1961); 254 pp.; $5.

Reviewed by R. J. Painter, ASTM Staff.

ANYONE WHO was ever stimulated and entertained by hearing Charles F. Kettering, and he spoke extemporaneously before many, many thousands of engineers and scientists, and others, will be delighted to know that ASTM Past-President T. A. Boyd, a close associate of Boss Ket for many years, has compiled and edited selections from many of his speeches. An American genius in invention and research, who gave America and the world so many valuable things, he was an inimitable speaker. He had a homespun manner, his stories were almost entirely original and peculiarly apt for the point he was making, and seldom if ever did he use notes or a manuscript. This writer heard him about a dozen times, and never saw him look at a piece of paper. Whenever and wherever he spoke, the people came out in large numbers to hear him. (The largest ASTM District Meeting ever, with about 950 present, was held in Detroit in the 1940's with Boss Ket as the main speaker.)

As Mr. Boyd points out in his introduction, Boss Ket had a solid background for all that he said. A farm boy, country school teacher, debater, and later an eminent engineer, inventor, and scientist with one the largest research institutions of its kind, which he established, he could speak with authority and from the heart. Practically all his speeches were impromptu and they had a spontaneity and informality which made them of utmost interest. Chapter headings in the book, each of which has a brief comment by the editor, include Opportunities Unlimited, Education for Tomorrow, Commencement Day, "Research" Is a High-Hat Word, Observations on Engineers, and Why is the Grass Green?

As one reads he almost feels in the presence of Boss Ket. From Mr. Boyd's many years of close contact, he has been able to edit the material so that the words seem spoken.

The book is replete with down-to-earth maxims on research, production, and many other things. Many a speaker would find it helpful to have a copy of this book in his file to serve as a vast fund of pertinent stories; and just from the standpoint of entertaining reading this book is excellent.

The book is the result of over two years of concentrated effort in finding and distilling material, and of many, many years of collecting and recording Boss Ket's comments and talks, which Mr. Boyd did throughout the later years of his contacts.

A wide host of pertinent topics are covered in Boss Ket's speeches—the future of America, the future of science, the automobile business, mass production, the role of education, and many others.

In the chapter on "Research" Is a High-Hat Word, there is this statement: "There is no magic about research—it is just plain hard work. I had a good friend who said to me: 'This research work is the most dramatic thing in the world—this getting new ideas, originating new things. I want to get my son into it.'"

Boss Ket's reply to this was, "Did you ever see a fly trying to crawl across a piece of sticky fly-paper? That is how dramatic research is—when you pull one foot out the other is sinking in.

"At best research is about 99 per cent failure, and one per cent success, and the one per cent is the only thing that counts. I have been inventing and researching for many years, but all our work on new things has been mainly drudgery . . .intelligent failure is a fundamental of research, but every time an experiment fails you should be careful to find out just why it failed . . ."

To some of the 50 maxims which appear in a special appendix to the book, such as "there are lots of folks with ox-cart minds riding around in automobiles," some of us would say "amen."

Boss Ket said "Self-satisfaction is one of the world's worst diseases." Also, "Don't think some fellow is trying to pull you down. You can always get a good sight of your enemy in the morning when you shave."

The closing words in the book are "So I want everyone to buy one or a hundred thousand shares of United States Preferred. Let's keep this the greatest nation that God ever let rest on the face of the earth."

It is of interest that two of Boss Ket's very close associates, F. O. Clements, technical director, General Motors Research Laboratories, and T. A. Boyd, responsible for the Fuel Division of the Research Laboratories, who were with Boss Ket in Dayton, were ASTM past-presidents, and at least one other national director came from the Laboratories. This indicates the interest of his associates in work in materials. He

(*Continued on page 323*)

(*Continued from page 320*)

himself was a member of ASTM from 1915 until his death in 1958.

No matter what one's activities and endeavors, reading this book will be highly entertaining and stimulating. It is so nice that we now have available many of Boss Ket's very pertinent comments.

And this reviewer concludes with a note of thanks to Past-President Boyd for the interminable hours spent in compiling and editing this publication. It may be pertinent to observe that Mr. Boyd's earlier book, *The Professional Amateur*, a biography of Charles Franklin Kettering, had a wide distribution.

Anti-Corrosion Manual, 1960 Edition, Corrosion Prevention and Control

97 Old Brompton Road, London S. W. 7 404 pp.; £ 3 plus 3/6d postage.

Reviewed by C. P. Larrabee, United States Steel Corp., Monroeville, Pa.

THIS ENLARGED edition of the 1958 and 1959 volumes contains 404 pages of manuscript, tables, and advertisements of British firms dealing in anti-corrosion measures and materials. Sections are titled: Corrosion in Industry, Resistant Materials and Their Applications, Preparatory Treatments for Protective Coatings, Protective Coatings, Mastics, Metallics, Spray Painting Methods, Pipe Coatings and Tapes, Protective Packaging, Water Treatment for Corrosion Control, Corrosion Testing, Cathodic Protection, and British Standards.

Somewhat of an innovation in this type of book is a large table showing the resistance of 28 plastics to 311 chemicals. The table would have been much easier to use if the data had been spaced into groups of five lines each.

The 43-page section on cathodic protection includes practical suggestions for the protection of pipelines, tank bottoms, ships, piers, and other installations, and a rather extensive mathematical consideration of the optimum locations for anodes used to protect the interiors of variously shaped tanks.

Under "Corrosion Testing" is a brief discussion of the limitations of salt-spray methods and a longer discussion on a Swiss aerosol method of accelerated laboratory testing. This test is claimed to duplicate the results of exposure to natural conditions; four variations are employed—the wet test, the natural test, the dry test, and the gas test. No data are presented to substantiate the claims, but eight literature references to this method are given.

The value of the book to readers of this country is reduced somewhat because alloys are not designated as they are in the United States, and in many instances are of different compositions. Moreover, most U. S. readers will not

(*Continued on page 336*)

MATERIALS AND TESTING TOPICS

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

FOR THE LABORATORY

Impedance Plotter—Higher and lower frequency ranges than were covered by earlier models are provided in the new AMCI Type 14 automatic impedance plotter. At the low end, an additional range of 0.1 to 2.5 Mc facilitates measurement of crystal-transducer impedances as well as other measurements in sonic and ultrasonic investigations. At the high end, an additional range of 1100 to 1700 Mc increases the over-all utility of the equipment.

Alford Manufacturing Co. 3688

Amplifier—The Model 516A is a new wide-band differential d-c amplifier. The instrument features three different plug-in front ends that make the basic unit three amplifiers in one. Economical circuit modification for several specific applications, which formerly required three special-purpose amplifiers, are made easily and inexpensively from the front panel. In addition to flexibility, important performance characteristics have been improved: frequency response to 40 kc, output impedance less than 0.05 ohm, drift less than 4 μv, common mode rejection 120 db.

Allegany Instrument Co. 3689

Chromatography Supplies — GAS-CHROM, a flux-calcined diatomite, is now available in new sizes for use as a chromatograph column packing support. The 140/170 and 170/200 mesh sizes are now offered in addition to the many other types. All of these can be obtained in the acid- and alcoholic-base washed grade as well as the regular and the acid-washed.

Applied Science Laboratories, Inc. 3690

Miniature Strip Chart—Without an amplifier the new A+ Record recorder requires only 400 μw for full response within 0.6 sec. Economically produced with a 4500-gauss magnet flux, the recorder is specifically designed to permit equipment manufacturers to obtain coil resistances and damping resistances matched to their own circuit characteristics. Much-improved recording can thus be obtained, often avoiding the cost and distortion resulting from amplification. Accuracy is within ± 1.0 per cent.

Atkins Technical, Inc. 3691

Laboratory Mixer—Production of a new vertical laboratory mixer has been announced. The new mixer, Model 60 LP, embodies design features that make possible laboratory mixing of high-viscosity fluids and castable polymers. Two synchronized intermeshing blades and close chamber tolerances ensure intimate mixing.

Atlantic Research Corp. 3692

Weight Comparator—A new, fully automatic, production-line electronic weight comparing system named the Atronic weight comparator, which automates the selection and screening of parts and materials by weight comparison, has been announced. When used in a processing or production operation it handles a continuously moving stream of parts or materials.

Atronic Products, Inc. 3693

Microscope—The DynaZoom line of microscopes has been especially created for laboratory use in educational institutions, public-health and hospital laboratories, industry, and many types of quality control work. It is the first laboratory microscope to feature a completely integrated zoom optical system. MicroZoom eliminates image blackout and focus shift, while permitting continuous, crystal-clear magnification within the entire range of the instrument. The magnification range of the series extends from 17.5 to 1940×.

Bausch & Lomb, Inc. 3694

Plastograph—A new, high-temperature recording plasticimeter called the C.W.B. "Plasticorder" has been developed. The instrument, which incorporates the C.W.B. "Plastograph" and a measuring head of new design with a vertical mixing chamber and shaft, is said to accurately forecast and record plastic properties of materials to 1150 F.

C. W. Brabender Instruments, Inc. 3695

Vibrascope—The GFB-DP Vibrascope is a research or production instrument measuring single-fiber linear density (or denier) with extreme ease and accuracy by vibrating the weighed fiber at constant frequency. The instrument is provided with special electrical means for handling and clamping the specimen so that an unskilled operator can obtain linear density (and subsequently average cross-sectional area) on a large, direct-reading, linear, vernier dial in about 1 min.

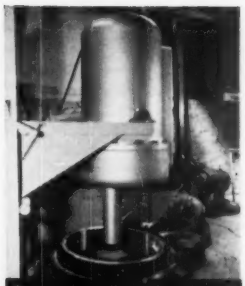
G. F. Bush Associates 3696

Strain Gage—A versatile instrument to provide continuous indication of pressure, torque, force, weight, or flow when used in conjunction with strain-gage transducers of the bonded or unbonded type has been developed. The Model 470 is packaged complete with transistor amplifier, power supply, and wide-scale meter eliminating the necessity for any additional instrumentation.

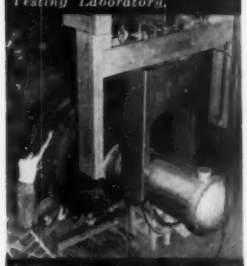
Bytrex Corp. 3697

Vacuum System—A new lightweight compact laboratory vacuum system for research laboratories, industrial production, and pilot plants has been announced.

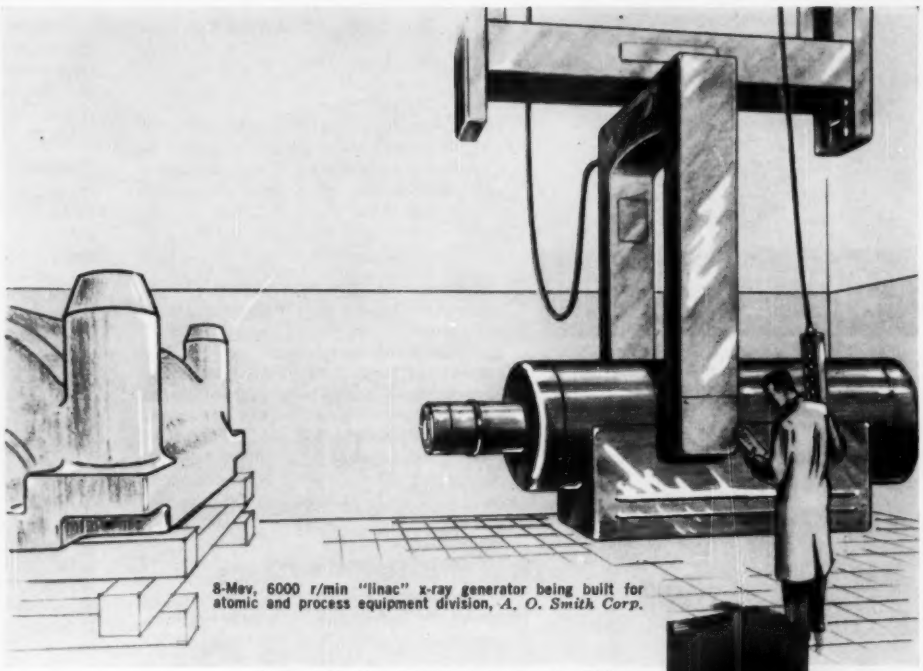
(*Continued on page 326*)



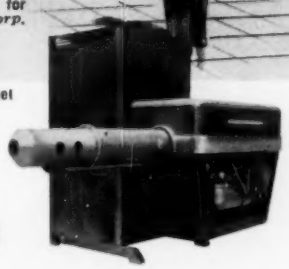
Panoramic radiography of steel weldment with 1-Mev Van de Graaff — *Arnold Greene Testing Laboratory.*



Radiography of circumferential seams of pressure vessel with 2-Mev Van de Graaff — *Foster Wheeler Corp.*



8-Mev, 6000 r/min "linac" x-ray generator being built for atomic and process equipment division, *A. O. Smith Corp.*



Radiographic Linac used for inspection of solid-fuel rocket motors by *Thiokol Chemical Corp.* ▶

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FOR FURTHER INFORMATION CIRCLE 1018 ON READER SERVICE CARD

FOR THE LABORATORY

(*Continued from page 324*)

Ideal for high-vacuum depositions of lightweight metals, this system features an implosion-proof, 18-in. diam, aluminum bell jar that can be evacuated within 5 min to a vacuum of 1 μ Hg, with an ultimate vacuum of 2×10^{-6} mm Hg.
Central Scientific Co. **3698**

Carbon-Hydrogen Analyzer—A new instrument for laboratory determination of carbon and hydrogen is being produced. Essentially an automated form of the time-tested Pregl method, the instrument permits rapid, accurate analysis of carbon and hydrogen in practically all classes of substances which pyrolize at temperatures under 1100 C. For routine analyses, the instrument yields results corresponding to theory within ±0.2 per cent carbon and ±0.2 per cent hydrogen; usual sample size is 5 to 50 mg.
Coleman Instruments, Inc. **3699**

Accelerometer—The development of the Model 706 accelerometer, a true compression-sensing device for measuring shock and vibration in missile and air-borne vehicles and in standard laboratory acceleration measuring systems has been announced. The Model 706 is a general-purpose unit that features simple bolt-down mounting through a central clearance hole.
Columbia Research Laboratories **3700**

Breadboard Testing—Static and dynamic output regulation and impedance measurements of regulated and unregulated power supplies can now be made by an electronic dynamic power supply analyzer, PSA-100. PSA-100 is a powerful tool for rapid analysis of breadboard supplies and production units.
Computer Sciences, Inc. **3701**

Ultrasonic Testing—The Model 424-D Immerscope has important new features that increase the flexibility and range of usefulness and additional detail refinements to make operation of the instrument easier and more convenient. The Immerscope is used for ultrasonic nondestructive testing of plates, ingots, pipe, tubing, forgings, castings, welds and other bonds, rolled shapes, honeycomb, extrusions, etc. Inspection is not limited to metal objects; other reasonably elastic materials such as glass, hard rubber, and ceramics can also be inspected.
Curtiss-Wright Corp. **3702**

Roundness Tester—The need for accurate measurement of errors in roundness has become increasingly important not only for missiles and space vehicles but for automated production lines as well. The new Model 2 has a work table designed to carry components weighing up to 1000 lb and shafts measuring up to 50 in. When necessary, the work table can be removed to provide additional work capacity. Measurements of roundness, concentricity, coaxiality, squareness, and interrupted circular shapes are permanently recorded on the Talyrond inkless polar chart.
Engis Equipment Co. **3703**

Sample Splitter—The Gilson porta splitter, a new portable sample splitter, has been announced. The new splitter halves and quarters samples of about ½ cu ft in sizes from sand up to 2-in. aggregate.
Gilson Screen Co. **3704**

Metallurgical Microscope—A new inverted metallurgical microscope that can instantly be converted into a microhardness tester or interferometer for measurement of surface finish, eliminating the necessity for separate instruments for such applications, is available. The new microscope can also be used for high-temperature microscopy by combining it with the Reichert vacuum heating stage for temperatures to 1800 C. Components for grain-size measurements and photomicrography can be adapted, and all transitions are instantaneous.
Wm. J. Hacker & Co., Inc. **3705**

Particle Size—A new particle-size analyzer permits the counting and classifying of approximately 1000 particles in less than 15 min. The analyzer is particularly valuable for analyzing photographs of particles taken with the electron microscope. It is about the size and weight of a typewriter. The equipment includes an ingenious diaphragm which activates 48 different counters.
The Harshaw Chemical Co. **3706**

Microwave Oscillators—A series of four microwave sweep oscillators each providing a leveled power output over its entire swept frequency range is now available. The new, highly versatile sweep oscillators include Model 682C, covering frequencies from 1.0 to 2.0 kMc; Model 683C, 2.0 to 4.0 kMc, Model 684C, 4.0 to 8.1 kMc, and Model 686C, 8.2 to 12.4 kMc.
Hewlett-Packard Co. **3707**

Tension Tester—Tension tests up to 500 lb can be accurately performed on a new portable instrument now available. Called the Series TJ tension tester, the new air-actuated unit is designed for bench mounting and easy operation. Its speed makes it ideal for production testing, and its accuracy, ±½ per cent of the full-scale reading, makes it suitable for exacting laboratory tension measurements.
Hunter Spring Co. **3708**

Rectifier Tester—A new, low-cost, 100-amp, 2000-v, dynamic rectifier tester for separate forward and reverse testing of semiconductor diodes has been produced. The equipment is constructed for use with an X-Y oscilloscope, for displaying the current-voltage characteristic. Forward and reverse voltages are independently adjustable. 0.5 per cent precision resistors are used in the critical measuring circuits for measurement of reverse leakage.
Instrument Development Corp. **3709**

Standard Samples — Standardization and calibration of carbon and oxygen analysis equipment, and graph preparation for conductometric carbon and oxygen determinations can be speeded and simplified through the use of LECO standard samples. The samples consist of high-purity compounds encased in tin capsules.

(*Continued on page 329*)

(*Continued from page 326*)

These are primary standards ensuring absolute accuracy. Weighing is unnecessary, since the appropriate standard is removed from the bottle ready for use.

Laboratory Equipment Corp. **3710**

Crystal Pulling Fixture—A dual-purpose fixture for crystal pulling and floating-zone applications for use with a high-frequency induction heating generator has been developed. The floating-zone method has been used extensively for zone refining and for growing crystals of high-purity silicon for semiconductor devices. This technique is particularly suitable for materials with a high melting point and high chemical reactivity. In the crystal pulling method, single crystals of various materials, especially germanium, have been successfully grown. In this method a seed of known crystal orientation is brought into contact with the surface of the molten metal and slowly withdrawn, producing progressive crystallization.

Lepel High Frequency Laboratories, Inc. **3711**

Magnet—An 8000-lb general-purpose electromagnet and power supply that provides a field intensity of 20,000 gauss over a large area (64 sq in.) with a 1½-in. gap has been announced. Ideal for a variety of laboratory applications, the MHD magnet assembly, coupled with a continuously variable power supply, is a most useful research tool. It is designed to operate at its maximum level for runs of 30 min. duration.

MHD Research, Inc. **3712**

Potentiometer—A new linear-motion conductive-plastic potentiometer with a stroke of 12 in. has been introduced. This potentiometer has a wire-wound element with high resolution and a standard linearity of 0.05 per cent—closer linearity can be supplied on special order.

New England Instrument Co. **3713**

Cement Tester—Compression and flexure testing of cement blocks, beams, and other specimens, with speed and precision previously available only with much larger testers, is now provided by the new 24,000-lb capacity Super "L" testing machine. By flipping a switch, the operator can instantly obtain any one of three load ranges—24,000, 12,000 or 600 lb. Range can be changed at any time during test.

Tinius Olsen Testing Machine Co. **3714**

Circuit Analyzer—A tester capable of executing dynamic and d-c tests on solid-state digital circuit modules has been developed. The unit permits complete tests of all 200-kc, 3-Mc, magnetic modules, and PB 250 computer modules now manufactured by Packard Bell Computer. Also incorporated in the unit are provisions for testing modules of future design in both standard and special configurations.

Packard Bell Computer Corp. **3715**

(*Continued on page 330*)

FOR THE LABORATORY

(*Continued from page 329*)

X-Ray Unit—A new X-ray image-amplifying technique that increases by five times the previous limits of effective fluoroscopic magnification and yields a clearer picture has been announced. A broad variety of inspection problems involving interior defects in parts or assemblies can be solved with the new image amplifier technique.
Picker X-Ray Corp. **3716**

Noise Analysis—A new, compact amplitude-distribution analyzer, designated Model 317, is announced. The Model 317 establishes the amplitude probability distribution of random signals and is useful for determining threshold requirements, error or false alarm probabilities, etc. A voltage threshold level is preset by a front panel control; noise levels exceeding the present voltage level are read, or monitored, by a scale calibrated in percentage—referred to time.
Quan-Tech Laboratories, Inc. **3717**

Hardness Gage—The new Rex rubber hardness gage, Model 1600, with an easy-to-read dial for laboratory and production work has been introduced. Large dial with 360-deg sweep gives ease of reading. Creep readings are easily noted by action of the dial hand. Durometer "A" scale is used. Hardness of rubber and other elastomers are measured instantly by holding the gage in a vertical position and pressing down until the entire foot encounters the specimen. Reading is given accurately to $\pm\frac{1}{2}$ Durometer point.
Rex Gauge Co., Inc. **3718**

Particle Monitor—By the addition of an air-dilution system to its Model PC200A airborne-particle monitor, Royco provides an instrument capable of accurately describing the spectrum of particles present in specimens of air ranging from clean-room atmospheres to the most polluted industrial smogs. In addition, the dilution system, available by itself, can be used in the laboratory to give an accurate means of mixing air or gases in controllable proportions.
Royco Instruments, Inc. **3719**

Potentiometer—A new marproof plastic case and internal improvements to widen application are features of the latest model Pyrotest portable potentiometer. The Pyrotest checks any thermocouple-actuated indicator, controller, or recorder; measures temperatures; and checks other potentiometers. Included as standard equipment are nine interchangeable, direct reading scales for use with any type of thermocouple.
Technique Associates **3720**

Isolation Table—The Tenlo TRV-1 vibration isolation table isolates sensitive equipment from horizontal vibration and motion. Horizontal vibration or motion of the bottom platform of the vibration isolation table is not transmitted to the top platform. Likewise, horizontal motion of the top platform is not transmitted to the bottom platform, so that the table may be used for the isolation of horizontal vibration either to or from the top platform.
Tenlo Research, Inc. **3721**

Blendor—Model CB-4 is a heavy-duty industrial model manufactured for laboratories, hospitals, and industry. Its ability to mix, blend, puree, and liquefy chemicals, foods, and concentrates makes it ideal for laboratory work. A heavy-duty motor ensures easy handling of viscous ingredients over long periods. Stainless steel blades and clamp are included as standard equipment.
Testing Machines, Inc. **3722**

Sieve Shaker—The TESTshaker, an improved sieve shaker suitable for use in the testing and grading of aggregate materials such as sand, gravel, asphalt, concrete, and the like, is available. The TESTshaker is adapted for use either in the laboratory or in the field.
TESTlab Corp. **3723**

Ultrasonic Cleaner—The diSONtegrator System Eighty, a $1\frac{1}{2}$-gal capacity ultrasonic cleaner, has been introduced. The System Eighty, guaranteed for 5 yr, features a broad-band frequency-modulated circuit which eliminates the need for automatic tuning. The generator is rated at 120-w average, 480-w peak power output.
Ultrasonic Industries, Inc. **3724**

Vacuum Accessories—New accessories consisting of a series of collars which fit in the vacuum system between the bell jar and the base plate of most commercial evaporators has been announced. Collar-base plate combinations as one-piece assemblies are also available.
Vacuum Technology, Inc. **3725**

Microscope—The Wild M-5 stereomicroscope, designed for first-order research in diversified applications, provides uniform, maximum sharpness throughout the field without change in accommodation. Standard magnifications of 6, 12, 25, and 50× can be conveniently selected on a rotatable horizontal drum, maintaining a constant working distance of 96 mm. Using accessory eyepieces and attachment objectives, a total power range of from 5 to 200× is obtainable.
Wild Heerbrugg Instruments, Inc. **3726**

Magnetic Stirrer—A new, budget-priced, magnetic-stirrer hot plate is now available. Called Gyratherm Junior, the new unit is designed for laboratory duties not requiring the greater heating capacity or stirring torque of the larger Gyratherm.
Will Corp. **3727**

X-Ray System—A new pulsed X-ray system with the ability to make cineradiographs of high-speed phenomena in 1 μsec or less is available. The equipment is expected to have widespread application in the fields of shock and vibration studies, radiation effects, rocketry, medical radiology, ballistics, and crystallography.
Zenith Radio Corp. **3728**

(*Continued on page 332*)

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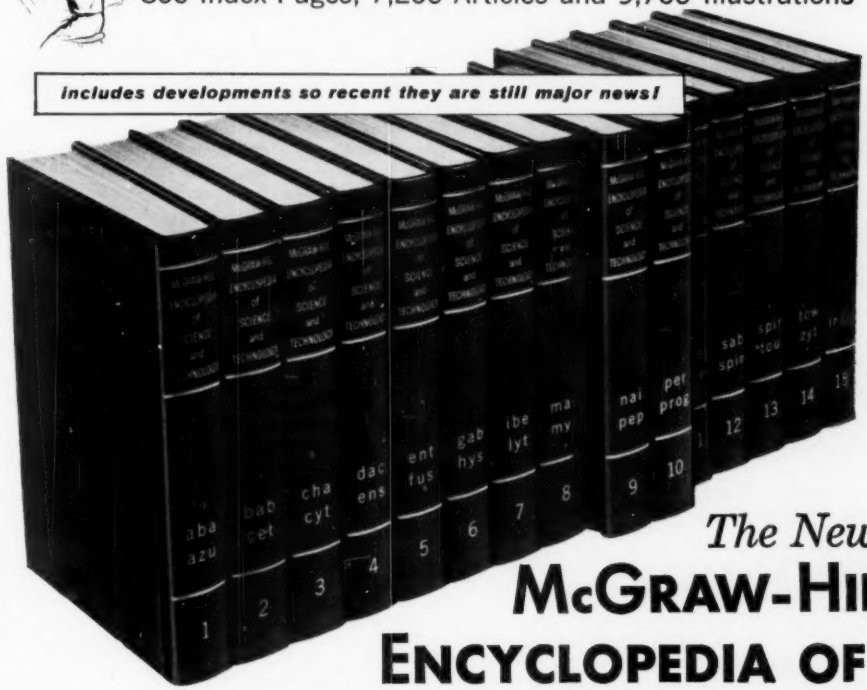

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NEW LITERATURE

Impulse Counter—*Bulletin No. N-310* describes the new Series 310 automatic reset impulse counter. Included are data on construction, application, installation, specialized functions, electrical data, and basic circuit arrangements.
Automatic Timing & Controls, Inc. 6403

Strain Gage—*Bulletin 4411* describes a new SR-4 pointer indicator and indicating controller designed for use in any bonded strain-gage transducer system. The Type 110 pointer indicator and indicating controller will be used in systems using Baldwin SR-4 transducers to measure weight, force, thrust, center of gravity, torque, and pressure.
Baldwin-Lima-Hamilton Corp. 6404

Water Demineralizers—Barnstead *Bulletin No. 154* introduces a complete line of disposable cartridge-type water demineralizers for use in chemical, hospital, electronic, nuclear, laboratory research, and pilot-plant operations. These demineralizers feature disposable cartridges in models up to 1500 gal per hr.
Barnstead Still and Sterilizer Co. 6405

Oxygen Sensor—A polarographic oxygen sensor is described in a new Beckman brochure. The sensor weighs 2½ oz, is 1½ by 2 in. in size, and has a delivery time of 60 to 90 days.
Beckman Instruments, Inc. 6406

Gas Analyzer—A two-page illustrated *Bulletin No. 1865* giving specifications and capabilities of a new CEC residual gas analyzer is now available. The mass-spectrometer-type instrument is designed to provide continuous analysis of gas remaining in evacuated systems. It is capable of measuring minute quantities of gas, gaseous mixtures, and vapors over a mass range of m/e 2 to 80.
Consolidated Electrodynamics Corp. 6407

Chromatographic Aid—Data sheet describes latest gas chromatographic accessory product, the Model T-300 d-c power supply. Especially designed for gas chromatography, Model T-300 replaces a battery as a source of power for thermistor or hot-wire gas chromatographic detectors. Included on the sheet are specifications and a chromatogram showing the stable baseline obtained with Model T-300 using 1-mv recorder operation.
F & M Scientific Corp. 6408

Measurement Cell—Two models of the oxidation-reduction potential cells, which measure the relative concentration of the oxidized and reduced forms of a substance present in a sample, are described in a specification bulletin for Model 17B1101. Design features, operational limits, and materials of construction are given along with dimensional drawings.
Fischer & Porter Co. 6409

Separations—A new booklet gives directions for the use of new support media in electrophoretic separations. The four-page publication gives directions for electrophoretic separations and staining techniques. It also lists advantages of the use of new materials and contains a bibliography of pages published on this subject.
Gelman Instrument Co. 6410

Transducer Systems—A series of articles on varied applications of high-accuracy transducer systems has been collected and released. Included in *Bulletin TD-105* are such diverse stories as electronic weigh loading of hot metal and pelletized ore; electronic weight, force, and thrust measuring on aircraft and missiles; strain-gage testing of the B-52G aircraft and USS *Albacore* submarine; calibration of transducers used in aerospace; and temperature testing to detect machinery parts failure.
Gilmore Industries, Inc. 6411

Power Supply—Power supply *Catalog No. 401* is now available. This new descriptive literature shows, in easy-to-read form, all electrical and mechanical specifications of Invar's 53 standard transistorized power supplies.
Invar Electronics Corp. 6412

Lime in Asphalt Paving—The National Lime Assn. has published *Bulletin 325*, "Hydrated Lime in Asphalt Paving," which relates how lime improves hot asphalt mixes. In this field lime serves as a stabilizing chemical additive which not only fills voids but also imparts strength, stability, and waterproofing qualities. As in soil stabilization, lime upgrades marginal pit-run materials into high-quality hot-mix aggregates. Generally, only small amounts of lime are required (1 to 2 per cent).
National Lime Assn. 6413

Radiation Alarm—A radiation warning system for any area where radioactive materials are stored, handled, or transported is described in new *Bulletin GA-2*. Known as the GA-2 gamma alarm system, it is a completely self-contained 12 by 15 by 8⅜ in. unit, with detector, power supply, fail-safe, and alarm circuits.
Nuclear Measurements Corp. 6414

Viscometers—A new 7-page catalog describing the complete line of Zeitfuchs viscometers is available.
Spira Glass 6415

Transducers—A new data folder containing a glossary of pressure transducer definitions and describing the SP-2 series pressure transducers is now available. The SP-2 series covers the range of 0 to 300 through 0 to 5000 psig. Four different models in the SP-2 series are described. The Model 100 is recommended for applications requiring accurate measurements of pressure taken in a small space under severe environmental conditions. Model 200 is a ruggedized and electrical flexible version of the basic SP-S unit. Model 300 was originally designed as a small pickup for use in the measurement of rocket nozzle pressures. The Model 600 is especially designed to make differential measurements at full system pressure.
Standard Controls 6416

Strain Gages—The new standard Strainsert bolt consists of strain gages installed in the neutral axis of the bolt shank, with

(*Continued on page 335*)

with precision, direct reading Hunter Mechanical Force Gages*—Series L type in 13 models for measuring load ranges from 0-500 grams to 0-30 pounds and Series D type in 6 models for measuring load ranges from 0-50 pounds to 0-500 pounds. Both types are accurate to better than 1% of full scale, can be provided with a "hold-at-maximum" indicator for registering maximum load, come complete with six attachments and wood carrying case. Thousands are now in use in laboratories, inspection departments, on production lines, and in the field. Send for Bulletin 750c containing full details including prices.

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CIRCLE 1034 ON READER SERVICE CARD

NEW LITERATURE

(*Continued from page 332*)

a screw-type connector embedded in the bolt head, without any reduction in allowable load or protrusion beyond the configuration of the ungaged bolt. Available in all external wrenching standard cap screw, hex head, and 12-point superstrength bolt sizes, the Strainsert bolt indicates bolt tension load with a guaranteed accuracy of better than 1 per cent, providing correspondingly high reliability and structural efficiency to bolts and bolted joints.

Strainsert Co. 6417

Recording Fluorometer—New data sheet describes the Turner Model 111 self-balancing fluorometer, which provides both direct readout and outputs for various types of recorders or controllers. Literature describes the optical-bridge design, the automated operation, and the sensitivity of 0.02-ppb quinine sulfate, which make the Model 111 useful in the rapidly expanding fields of trace analysis, clarity determinations, air and water tagging, and other fluorescence measurements.

G. K. Turner Associates 6418

Liquid Gage—*Bulletin No. CP3709* on the new Varec Figure No. 8400 series high-pressure "Dynamatic" liquid level gage is now available. The 4-page bulletin explains the operation and unique features of this electrically powered tank gage, which is calibrated to $\frac{1}{16}$-in. The electric power drive in the gage eliminates errors due to friction.

The Vapor Recovery Systems Co. 6419

MATERIALS

Silicone Rubber—A 4-page illustrated bulletin which describes and provides data on the various kinds of silicone-insulated cable manufactured is available. Entitled "Single and Multiconductor Cable with Silicone Rubber," the new bulletin features power and lighting cable, hook-up wire, ignition cable, as well as a list of conductor cable for shipboard, missiles, and nuclear power purposes.

Boston Insulated Wire & Cable Co., Boston, Mass.

Pure Silver—Using a new atomic recombination process, High Purity Metals, Inc., the ultra-pure metals division of Accurate Specialties Co., Hackensack, N. J., has been able to offer industry 99.999+ per cent pure silver for semiconductor and other applications.

High Purity Metals, Inc., Hackensack, N. J.

Damping Tape—Designed for easy application on thin sheet metal, a new vibration damping tape consisting of foam, plastic, and high-tack adhesive has been introduced. Called "Scotchfoam" brand vibration damping tape No. Y-9052, the new permanent-adhering pressure-sensitive tape is designed to reduce resonant vibration and accompanying noise by converting vibration energy into heat. Conformable even to rough and irregular surfaces, the tape can be rapidly applied with just finger pressure against its plastic backing. No application tools are required.

Minnesota Mining and Manufacturing Co., St. Paul, Minn.

Perlite—The new 1961 issue of the Perlite lightweight plaster aggregate catalog, identified as *A.I.A. File Nos. 21-A-5 and 21-C-1*, is available to contractors, architects, engineers, and builders. It describes in detail specifications for perlite aggregate plaster covering materials, basecoat, recommendations, finish coat application, as well as mix proportion, thermal conductivity, and sound reduction data. In addition data are provided for lightweight fireproofing of walls, partitions, ceilings, columns, and beams.

Perlite Institute, Inc., New York, N. Y.

Silicones—A new and comprehensive booklet on silicones containing the most recent and advanced information on these important man-made chemicals has been issued, as an aid to engineers and technical personnel. Graphically illustrated with photographs, charts, and graphs, the booklet goes into detail about what silicones are, describes their manifold uses for consumer and industrial products, and suggests ways in which they can be adapted to a host of new applications by the de-

(*Continued on page 336*)

MATERIALS

(*Continued from page 335*)

sign engineer or product development manager. Of special significance is the series of charts covering the properties and features of fluids, resins, rubber compounds, water repellents, antifoams and emulsions, and their adaptability for use by the aviation, automotive, chemical, electronic, rubber, paint, paper, textile, glass, metal-working, and other industries.

Union Carbide Corp., New York, N. Y.

LABORATORIES

General Testing & Inspection Agency, Inc., Portland, Ore.—announces the addition of a complete wood laboratory to its facilities, which, since 1953, have been serving the Western States as a glue-lamination inspection agency and chemical consulting service. The new wood laboratory will serve industry in the areas of product development, materials testing, quality control, preservative treated products, and wood utilization.

Technical Aid Service, Inc., Columbus, Ohio—is now offering a service especially tailored for management and research and development staffs of electronics, petroleum processing, petrochemical, chemical, pharmaceutical, and related firms. The service entails the reduction of technical literature to easily understood digests of basic principles. These digests are integrated into an intelligent retrieval system. These short summaries of technical data, free from irrelevant terminology and redundant detail, can be scanned and understood in a few minutes by scientific personnel. Personnel are kept apprised of new developments as well as prior accomplishments revealed in technical literature.

BOOKSHELF

(*Continued from page 323*)

make use of the numerous advertisements. Its major appeal will be to the student and engineer who wish a source of general information on corrosion prevention by use of various constructional materials.

The Extrusion of Metals

C. E. Pearsons and R. N. Parkins; Second Edition Revised, John Wiley & Sons, Inc., New York, N. Y. (1960); 336 pp.; $7.50.

Reviewed by J. W. Caum, ASTM Staff

EXTRUSION AS A method for production of wrought metallic shapes made gigantic strides forward during World War II. It would be difficult to estimate the contribution that extruded products of all kinds made toward meeting the insistent demands of the armed services. This book was first published in 1944 and was reprinted with revision in 1953. Now the ad-

vances in the technology and science of extrusion are such that they can no longer be accommodated by revisions of the original edition. For example, a special chapter deals with the theoretical analysis of flow in extrusion, which should serve as a valuable guide to industrial practice.

Increased efficiency is resulting from the trend toward fully automatic presses. Very powerful units permit the production of much larger sections and can now work routinely many alloys previously considered marginal. The use of glass as a high-temperature lubricant has overcome many of the earlier obstacles to the economic extrusion of steel and other alloys. Since the process deforms the metal under predominantly compressive forces, it has proved attractive for working many of the newer metals. Stepped extrusions and composite billets for making clad products are further extended uses of the extrusion process.

It would be easy to become too enthusiastic over the novelty and possible applications of the extrusion process. However, the authors have properly maintained a correct perspective in their treatment of the recent developments.

Concrete Research Conference

THE SECOND CONFERENCE on Fundamental Research in Plain Concrete will be held at the University of Illinois Conference Center, Allerton Park, near Monticello, Ill., from September 5 to 8, 1961. The conference will afford an opportunity for discussion at the fundamental level of such topics as kinetics of hydration, rheology of concrete, origin and nature of strength, fracture, and aggregate reactions. Because of the nature of the conference, it is anticipated that only those most intimately associated with the field of concrete will participate. The conference fills a need that arises from the interrelationship of the several disciplines involved in concrete research.

The sponsors are: American Concrete Inst., American Society of Civil Engineers, American Society for Testing Materials, Portland Cement Assn., Reinforced Concrete Research Council, and the University of Illinois. The conference is supported by the National Science Foundation.

The Conference Center has complete facilities for lodging, meals, and meeting rooms. The atmosphere will be such as to allow the participants to "live" concrete for three days.

Available facilities will limit the attendance at the conference to about 100 persons invited by the steering committee. Anyone who wishes to attend the conference should write to Prof. Clyde E. Kesler, Department of Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill.

NEWS OF MEMBERS

A. W. Attwooll, assistant technical director, The Limmer and Trinidad Lake Asphalt Co., Ltd., London, England, retired recently. Mr. Attwooll joined the Society in 1955.

Don Bailey, formerly design engineer, National Cash Register Co., Inglewood, Calif., is now consulting engineer, Capital Service Co., Hawthorne, Calif.

W. M. Baldridge, research engineer, Laclede Steel Co., Alton, Ill., retired recently. Mr. Baldridge has been active in the Society and in Committee A-1 on Steel since 1947.

Jackson Bauer is now director, Textile Laboratories, Quaker Chemical Products Corp., Conshohocken, Pa. He had been director of research, Automotive Div., Collins & Aikman Corp., Albermarle, N. C.

Karnig A. Berberian is with Norden, Division of United Aircraft Corp., Bridgeport, Conn. Formerly he was materials engineer, Sperry Semiconductor Div., Sperry Rand Corp., South Norwalk, Conn.

R. R. Brady, until recently assistant technologist, United States Steel Corp., Monroeville, Pa., is now serving in the same capacity with Lee Wilson Engineering Co., Inc., Monroeville, Pa.

A. B. Cornthwaite, ASTM director, is now managing engineer, Atlantic-Gulf Div., The Asphalt Inst., Washington, D. C. Formerly he was engineer of materials and tests, Commonwealth of Virginia, Department of Highways, Richmond, Va.

Harry P. Croft has been elected vice-president, research, Copper Range Co., New York, N. Y. Previously he was with Kennecott Copper Corp., New York, N. Y.

H. J. Cutler, a member of ASTM since 1924, retired January 31, 1961, as engineer of tests, Bethlehem Steel Co., Inc., Lackawanna, N. Y. Mr. Cutler was an active member of Committee A-1 on Steel.

Theodore R. Donlan, Research Div., Marketing Technical Section, Esso Research and Engineering Co., Linden, N. J., retired March 1, 1961. He will, however, continue to do consulting work. Since joining the Society in 1939, Mr. Donlan has been active in Committees D-1 on Paint, Varnish, Lacquer and Related Products, D-12 on Soaps and Other Detergents, D-2 on Petroleum Products and Lubricants, D-16 on Industrial Aromatic Hydrocarbons and Related Materials, D-15 on Engine Antifreezes, and several subcommittees of E-1 on Methods of Testing.

J. L. Dreher has been promoted from group supervisor to supervising research chemist, Greases and Industrial Lubricants Section, Richmond Laboratory, California Research Corp., San Francisco, Calif.

James A. Ford, formerly an instructor, University of Michigan, Ann Arbor, Mich., is a research scientist, United Aircraft Corp., East Hartford, Conn.

Leonard G. Ghering, president, Preston Laboratories, Inc., Butler, Pa., is now chairman of the board.

Gary G. Guthrie is quality control engineer, ITT Kellogg, Orcutt, Calif. Formerly he was quality control liaison, Burroughs Corp., Pasadena, Calif.

Albert G. Haynes, previously director, Keeney Research Div., Inc., Subsidiary of J. H. Keeney and Co., Chicago, Ill., is development engineer, Electro-mechanical Laboratories, Seeburg Corp., Chicago, Ill.

Henry H. Hemenway, director of research and engineering, Graver Tank and Manufacturing Co., Division of Union Tank Car Co., East Chicago, Ind., has been appointed vice-president, research and engineering.

Fred Hubbard, consulting engineer, The Standard Slag Co., Youngstown, Ohio, retired recently. Mr. Hubbard's activities in ASTM go back to 1926 when he began his individual membership and was elected to membership on Committee C-9 on Concrete and Concrete Aggregates. A few years later he joined Committee D-4 on Road and Paving Materials. Recently both of these committees elected him to Honorary Membership in recognition of his outstanding work and long and faithful service. Mr. Hubbard represents the National Slag Assn. on Subcommittee 10 of E-1 on Methods of Testing and ASA Z-23 on Specifications for Sieves for Testing Purposes.

John T. Hugill is manager, tonnage products sales, Air Reduction Sales Co., New York, N. Y. Formerly he was with Canadian Liquid Air Co., Montreal, P. Q., Canada.

Claude H. Jensen, electrical engineer, Copperweld Steel Co., Glassport, Pa., retired December 1, 1960. Mr. Jensen was a member of Committee B-1 on Wires for Electrical Conductors and a consulting member of Committee A-5 on Corrosion of Iron and Steel.

Herbert F. Kleinhans is president, Luce Reflexite Corp., South Norwalk, Conn. He had been manager, product development, Pawling Rubber Corp., Pawling, N. Y.

Earl W. Klinger, marketing technical service, Esso Research and Engineering Co., Esso Research Center, Linden, N. J., retired March 1, 1961. Mr. Klinger has been a member of the Society for 20 years, and during this time participated in the

(*Continued on page 341*)

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Goodrich Gulf Chemical Co.
Goodyear Tire & Rubber Co.
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Phillips Chemical Co.
Texas U.S. Chemical Co.
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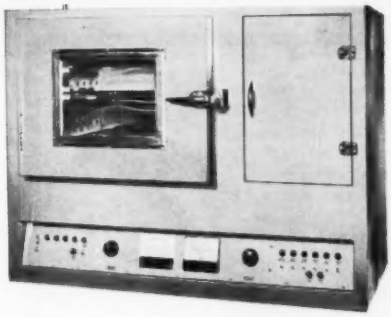
U. S. Rubber Company
Shell Chemical Corporation



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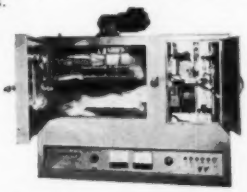

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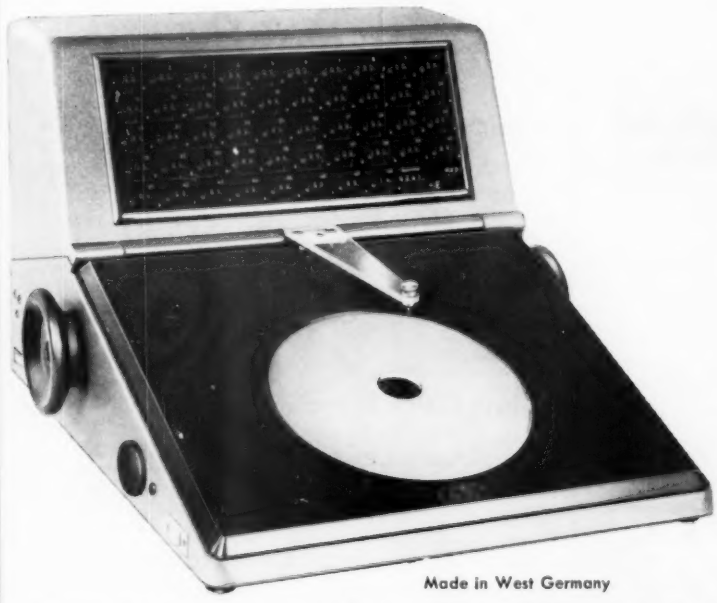

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NEWS OF MEMBERS

(*Continued from page 338*)

activities of Committees D-4 on Road and Paving Materials, D-8 on Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses, and D-18 on Soils for Engineering Purposes.

George S. Laaff is now with the Standard International Corp., Andover, Mass. Previously he was manager, Bolta Products, Division of The General Tire & Rubber Co., Lawrence, Mass.

Harold J. Levine, vice-president and manager, National Brick Corp., Long Island City, N. Y., retired recently. Mr. Levine's membership in ASTM dates back to 1931. He was a former member of Committee C-15 on Manufactured Masonry Units.

H. Luttringhaus is now technical director and vice-president, Carbic-Hoechst Corp., Westfield, N. J. Formerly he was chemist, Intercontinental Chemical Co., New York, N. Y.

Robert S. Mercer is now department head, Research and New Products Div., Haveg Industries, Inc., Wilmington, Del. Previously he was development chemist, Pennsalt Chemicals Corp., Natrona, Pa.

William J. Morgan has joined E. W. Bliss Co., Canton, Ohio, as chief metallurgist. He had been research engineer, Walker Manufacturing Company of Wisconsin, Jackson, Mich.

Albert G. Morris, formerly senior research chemist, Foote Mineral Co., West Chester, Pa., is now director of research, United Mineral and Chemical Corp., New York, N. Y.

C. F. Nixon, head, Electrochemistry and Polymers Dept., Research Laboratories, General Motors Corp., Warren, Mich., received an SAE Certificate of Appreciation in recognition of his contributions to SAE technical committees.

Douglas E. Parsons, Honorary Member of ASTM, and chief, Building Technology Div., National Bureau of Standards, Washington, D. C., was selected "This Month's Standards Personality" by the American Standards Association in January.

Earl H. Porter, by-products chemical engineer, Public Service Electric and Gas Co., Camden, N. J., retired December 31, 1960, but will remain with the company as a consultant. Mr Porter has held membership in the Society since 1932, and has participated in the activities of Committees D-4 on Road and Paving Materials and D-18 on Soils for Engineering purposes.

Alex Sacher is now president, Dimensional Pigments, Inc., Bayonne, N. J. He had been technical director, Standard Insulation Co., East Rutherford, N. J.

R. W. Seniff, vice-president of ASTM, has been appointed manager, tests and engineering, Motive Power Dept., Baltimore & Ohio Railroad Co., Baltimore, Md. He had been manager of research.

Henry Shaw has joined Socony Mobil Oil Co., Inc., Plainsboro, N. J., as research chemical engineer. He was in the Materials and Testing Dept., The Babcock & Wilcox Co., Lynchburg, Va.

E. O. Slater, president and manager, Smith-Emery Co., Los Angeles, Calif., retired December 31, 1960. Mr. Slater represented his company in Society membership and was an active member of the Southern California District Council. He was council secretary from 1934 to 1942, vice-chairman from 1942 to 1944, and chairman from 1944 to 1946.

John C. Smack, formerly with the Princeton Div., Curtiss-Wright Corp, is now a consultant in the field of nondestructive testing at Mountain Lakes, N. J.

I. Melville Stein, president of Leeds & Northrup, Philadelphia, Pa., was honored recently by being named "Philadelphia Engineer of the Year." The award was made during National Engineers' Week under the sponsorship of the Philadelphia Chapter, Pennsylvania Society of Professional Engineers. For many years, Mr. Stein represented Leeds & Northrup in Society membership.

Stephen Teleshak, formerly metallurgist, United Engineering and Foundry Co., Vandergrift, Pa., is manager, Metallurgical Dept., Pittsburgh Testing Laboratory, Pittsburgh, Pa.

Harold R. Terhune has been installed as president, Standards Engineers Society. Mr. Terhune, manager of standards, ITT Laboratories, Nutley, N. J., represents his company in Society membership.

W. C. Wagner has established the Albuquerque Testing Laboratory, Albuquerque, N. Mex. Formerly he was associate professor of civil engineering, University of New Mexico, Albuquerque, N. Mex.

W. W. Walton has been appointed chief of the Organic Building Materials Section, Building Research Div., National Bureau of Standards, Washington, D. C. Previously he had been chief, Surface Chemistry Section, Chemistry Div.

Robert W. Webb, U. S. Dept. of Agriculture, Cotton Div., A.M.S., Washington, D. C., a former active member of Committee D-13 on Textile Materials, has had his accomplishments in the field of cotton technology recorded in the Congressional Record for September 2, 1960.

Reginald V. Williams, president, Williams Gold Refining Co., Buffalo, N. Y., retired recently. Mr. Williams' membership in ASTM extended over a period of 37 years.

Leonard A. Wohler has been named manager, latex sales, Firestone Synthetic Rubber & Latex Co., Akron, Ohio.

DEATHS

Carl Bussow, chief chemist, A. W. Dow, Inc., New York, N. Y. (January 17, 1961). Mr. Bussow joined the Society in 1935, and was actively serving on Committees D-8 on Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses and D-4 on Road and Paving Materials.

Charles V. Cooper, president, Aluminum, Inc., Fort Lauderdale, Fla. (recently). Mr. Cooper had been a member of the Society for only a short time.

Charles T. Evans, Jr., vice-president, technology and development, Universal-Cyclops Steel Corp., Bridgeville, Pa. (February 8, 1961). Mr. Evans had been active in the Society since 1945, having served on Committees A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys, and A-1 on Steel.

J. J. Gould, consulting engineer, John J. Gould & H. J. Degenkolb, San Francisco, Calif. (January 30, 1961). Mr. Gould joined ASTM in 1950, and was a member of the Northern California District Council.

H. R. Lillie, manager, Research and Development Div., Corning Glass Works, Corning, N. Y., was killed in the plane that crashed in Brussels, Belgium, February 15, 1961. Dr. Lillie was a member of Committee C-14 on Glass and Glass Products. He was on his way to attend a meeting of the International Commission on Glass, of which he was president.

Francis A. McAdam, director of research and development, Huron Portland Cement Co., Detroit, Mich. (February 12, 1961). Mr. McAdam had been a member of the Society for 20 years.

MATERIAL QUESTIONS

NEARLY EVERY day the mail at ASTM Headquarters includes some questions about materials, specifications, test methods, or related problems. We feel that the answers, many of which are based on information given us by officers of committees in their capacity as committee officers, are of general interest. For the most part inquiries we receive relate to the activities of the Society, either standards, research work, or publications. Often, an inquiry is such that the services of a consultant or independent testing or research laboratory is obviously required; in this event we do not hesitate to so recommend.

Superficial Hardness Testing

Table I of ASTM Methods E 18 for Rockwell hardness testing states that scale A can be used on cemented carbides, thin steel, and shallow-case-hardened steel. Other authorities state that the case depth of case-hardened steel should be at least ten times the depth of indentation. To avoid confusion, I should like to propose that Methods E 18 be amended to include this limitation.

We recently experienced an argument arising from the fact that some steel washers complied with specification A 325 when tested on a Vickers hardness tester, but not when tested on the Rockwell A scale. Specification A 325 requires that carburized washers have a hardness of 68 to 75 Rockwell A and be carburized to a minimum depth of 0.015 in. At these hardness values the depths of indentation are between 0.0033 and 0.0026 in., or about one fifth of the case depth.

● Your proposal to include a statement on the relationship of case depth to indentation depth was discussed at the February 1961 meeting of Subcommittee 6 on Indentation Hardness of Committee E-1 on Methods of Testing. The consensus was that this is indeed a problem, but that it is a different problem for different products, and would therefore better be handled in the various product committees.

It would appear that, in the case cited, the washers did not comply with the specification, since the Rockwell A hardness did not fall within the specified range. A hard superficial layer might well give a high DPH hardness, while the depth-hardness pattern results in a low Rockwell A hardness.

Correct limiting thickness requirements for hardness testing are extremely difficult to establish. Practical use of hardness testers could be hampered if all limits were set so as to eliminate completely anvil effect or the effect of a soft underlayer. The most satisfactory thickness limits are those established by experience for a specific application, with hardness limits that accommodate any anvil effect that might be present.

Tension Testing of Polyethylene

In the tension testing of polyethylene covered in the specification for this material, D 1248, what is the basis for selecting the testing speed of 2 in. per min rather than some higher or lower speed?

● The recommended speed represents the best judgment of the majority of those contributing to the last major revision of this specification and was adopted without dissenting vote in the Committee D-20 letter ballot which approved the revision. The question of proper testing speed was discussed at length.

Recognizing that a speed of 20 in. per min begins to approach tensile impact for the most rigid of these materials, many workers favored drastically lower speeds. 0.2 in. per min, or even less. Because each test takes so much time at the very low speeds and because test results at 2 in. per min were very nearly the same as those at 0.2 in. per min, the former was deemed a good, practical compromise.

Lack of reproducibility at the slower speeds can, of course, result from a number of possible causes. Variations in the thermal history of the specimen can contribute, as can the presence of flaws, particularly at the edges of the specimen. Increasing the speed of testing tends to bury the effects of such variations along with true minor differences between materials.

CALENDAR

May 21–25—**Building Officials' Conference of America,** 46th Annual Conference, Bellevue-Stratford Hotel, Philadelphia, Pa.

May 22–26—**American Society of Tool and Manufacturing Engineers,** Tool Show, and Annual Convention, New York, N. Y.

May 28–June 1—**Special Libraries Assn.,** San Francisco, Calif.

May 31–June 2—**The Engineering Institute of Canada,** Annual Meeting, Vancouver, B. C.

June 4–7—**National Association of Purchasing Agents,** 46th Annual International Convention and Inform-A-Show, Conrad Hilton Hotel, Chicago, Ill.

June 4–9—**Zinc Development Assn.,** Sixth International Conference on Hot-Dip Galvanizing, Kursaal, Interlaken, Switzerland.

June 5–7—**Edison Electric Inst.,** Annual Convention, Waldorf-Astoria Hotel, New York, N. Y.

June 5–7—**American Society for Quality Control,** Annual Convention and Exhibition, Sheraton Hotel, Philadelphia, Pa.

June 5–9—**Society of the Plastics Industry,** 9th National Plastics Exposition and Conference, Coliseum and Commodore Hotel, New York, N. Y.

June 5–9—**Society of Automotive Engineers,** Summer Meeting, Chase Park Plaza, St. Louis, Mo.

June 7–9—**National Electrical Manufacturers Assn.,** Western Conference, Hotel Biltmore, Los Angeles, Calif.

June 9–17—**The ACHEMA 1961,** 13th Exhibition Congress of Chemical Engineering, Frankfort am Main, Germany.

June 11–15—**American Society of Mechanical Engineers,** Summer Annual Meeting, Statler-Hilton, Los Angeles, Calif.

June 13–16—**Institute of Aerospace Sciences** and **American Rocket Society,** Hotel Ambassador, Los Angeles, Calif.

June 18–22—**Forest Products Research Society,** 15th National Meeting, Kentucky Hotel, Louisville, Ky.

June 18–23—**American Institute of Electrical Engineers,** Summer General Meeting, Cornell University, Ithaca, N. Y.

June 19–22—**American Electroplaters' Society,** 48th Annual Convention, Statler-Hilton Hotel, Boston, Mass.

June 19–24—**American Association for the Advancement of Science,** Pacific Division Meeting, University of California, Davis, Calif.

June 25–28—**American Society of Agricultural Engineers,** National Meeting, Iowa State University, Ames, Iowa.

June 26–28—**American Society of Heating, Refrigerating and Air-Conditioning Engineers,** Annual Meeting, Statler Hilton Hotel, Denver, Colo.

June 26–30—**American Society for Engineering Education,** Annual Meeting, University of Kentucky, Lexington, Ky.

June 28–30—2d Joint Automatic Control Conference, Sponsored by **ISA, AIChE, AIEE, ASME, and IRE,** University of Colorado, Boulder, Colo.

NEW MEMBERS

The following 172 members were elected from February 8, 1961, to March 9, 1961, making the total membership 10,415 . . . Welcome to ASTM. Names are arranged alphabetically, company members first, then individuals. Your ASTM Year Book shows the areas covered by the respective Districts.

Central New York District

Eichenlaub, Paul W., manager of works laboratory, Oneida, Ltd., Sherrill, N. Y.
Montwill, Maria, librarian, Technical Department Library, Behr-Manning Co., A Division of Norton Co., Troy, N. Y.
Stearns, Donald E., partner, Stearns & Wheler, Cazenovia, N. Y.

Chicago District

National Corrugated Metal Pipe Assn., Roy E. Smith, managing director, Chicago 3, Ill.
Austenfeld, Robert S., product engineer, Fansteel Metallurgical Corp., North Chicago, Ill. [A]*
Barnett, W. R., assistant chief metallurgist, U. S. Steel Corp., Gary Steel Works, Gary, Ind.
Bazzell, Charles K., engineering department head, Goodell Engineering Associates, Champaign, Ill.
Berger, E. Jerome, chief test engineer, Toro Manufacturing Corp., Minneapolis, Minn.
Bernacke, Frank M., chief of bureau, Bureau of Air Pollution, East Chicago, Ind.
Coulon, Noah, Jr., chief production engineer, Hoffman Electronics Corp., Evanston, Ill.
Hartzell, Paul D., manager, Metallurgical and Materials Engineering Div., Caterpillar Tractor Co., East Peoria, Ill.
Holston, Marc, plant superintendent, Chicago Curled Hair Co., Chicago Heights, Ill.
Johnston, Lee G., manager of laboratories, American Institute of Laundering, Joliet, Ill.
Kirschner, Leon, director, Industrial Hazard Analysts, Skokie, Ill.
Kressin, Erwin G., quality manager and liaison engineer, General Controls Co., Iron Mountain, Mich.
Kubala, Roman R., manager, Webcor Testing Laboratories, Webcor, Inc., Chicago, Ill.
Larson, Charles M., sales manager, Charles E. Larson and Sons, Inc., Chicago, Ill.
McCulloch, William C., president, Roberts & Schaefer Co., Chicago, Ill.
McKee, Frank J., National Dairy Products Corp., Glenview, Ill.
Naslund, Kenneth C., president and partner, The Engineers Collaborative, Chicago, Ill.
Schwartz, Roy C., chief engineer, Galland & Henning Manufacturing Co., Milwaukee, Wis.
Spear, Lester H., chief chemist, Blocksom and Co., Michigan City, Ind.
Togami, Paul G., design engineer 1, International Harvester Co., East Moline, Ill. [A]

Cleveland District

Clifford, Richard J., metallurgical engineer, Bendix Westinghouse Automotive Air Brake Co., Elyria, Ohio.
Guran, John D., engineer, M. B. Guran Concrete and Supply Co., Akron, Ohio.
Swafford, H. D., head of analytical laboratories, Glidden Research Center, Cleveland, Ohio.

Detroit District

Birch, Norman A., technical director, Albion Malleable Iron Co., Albion, Mich.
Bonus, Robert M., president, Hay-Contile Co., Detroit, Mich.
Cooper, Maurice D., head, Chemistry Dept., Research Laboratories, General Motors Corp., Warren, Mich.
Fox, M. C., chief inspector, Monroe Auto Equipment Co., Monroe, Mich.
Ip, Ping-Yu, research metallurgist, Walker Manufacturing Co., Jackson, Mich.
Risk, Thomas Harrison, manager, Materials, Fuels and Lubricants Dept., Ford Motor Co., Product Study Engineering Office, Dearborn, Mich.
Shackman, Norman, assistant director, Research and Development, I-T-E Circuit Breaker Co., Bulldog Div., Detroit, Mich.

Mississippi Valley District

Arkansas State Highway Dept., H. W. Schneider, engineer of materials and tests, Highway Bldg., Little Rock, Ark.
Bay, Robert Dewey, research engineer, Laclede Steel Co., St. Louis, Mo.
Blair, Edward B., manager, Metallurgical and Inspection Dept., Laclede Steel Co., St. Louis, Mo.
Cable, George W., head, Central Div., Research Dept., C. K. Williams and Co., East St. Louis, Ill.

(*Continued on page 346*)

* [A] denotes Associate Member.

NEW MEMBERS

(*Continued from page 345*)

Gabbard, Thomas H., production manager, Procter & Gamble Manufacturing Co., St. Louis, Mo.
Goetz, Margaret C., specification dept., Dan R. Sandford and Sons, Kansas City, Mo.
Hoff, Philip L., sales engineer, Marquette Cement Manufacturing Co., St. Louis, Mo.
Jackson, Lloyd C., materials engineer, The Bendix Corp., Kansas City Div., Kansas City, Mo.
Middien, Ismail F., analytical chemist, Consumers Cooperative Assn., North Kansas City, Mo.
Ponciroli, Kenneth L., assistant chief metallurgist, Laclede Steel Co., Alton, Ill. [A]

New England District

Improved Seamless Wire Co., The, Clarence J. Smith, metallurgist, Providence, R. I.
Cherbonneau, Vincent E., laboratory supervisor, A. G. Spalding and Bros., Inc., Chicopee, Mass.
Folsom, Allan G., group leader, product engineer, Laboratory, Bolta Products Div., The General Tire and Rubber Co., Lawrence, Mass.
Holland, Henry, fabric development director, Ansonia Mills, Inc., East Taunton, Mass.

New York District

Isotronics, Inc., Samuel J. Strindberg, process engineer, Lodi, N. J.
Philips Laboratories, A. L. Fessler, librarian, Irvington-on-Hudson, N. Y.
Averill, Edward R., supervisor, Engineering Laboratory, America Fore Loyalty Group, New York, N. Y.
Brown, Charles S., technical advisor, Russell Burdsall and Ward Bolt and Nut Co., Port Chester, N. Y.
Dietz, Albert, assistant director of technical service, American Cyanamid Co., Pigments Div., Bound Brook, N. J.
Disque, Fredrick C., Jr., director of research, Alpha Metals, Inc., Jersey City, N. J.
Fiorillo, Raymond C., laboratory director, National Concrete Corp., Long Island City, N. Y.
Huff, Thomas A., vice-president in charge of manufacturing, Hightstown Rug Co., Hightstown, N. J.
Kinelski, Eugene H., metallurgical engineer, Alloy Product Development, The International Nickel Co., Inc., New York, N. Y.
Moe, Rolf, Jr., Sales Dept., Maritime Chemical and Repair Corp., Brooklyn, N. Y. [A]
Morgan, D. L., chief engineer, Robertshaw-Fulton Controls Co., Bridgeport Thermostat Div., Milford, Conn.
Oikawa, Toshiichi, director, Maruzen Petrochemical Co., Ltd., New York, N. Y.
Randall, G. E., manager, Research Library, International Business Machines Corp., Yorktown Heights, N. Y.
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Schirmer, Henry G., chemical engineer, Personal Products Corp., Milltown, N. J. [A]
Sharpe, Robert Q., manager, Industrial Div., Products Dept., Socony Mobil Oil Co., Inc., New York, N. Y.
Weber, George, associate engineer, Allen B. DuMont Laboratories, Division of Fairchild Camera and Instrument Corp., Clifton, N. J.

Northern California District

Bayce, Arthur E., metallurgist, Shell Development Co., A Division of Shell Oil Co., Emeryville, Calif.
Blair, E. G., owner and manager, Blair Industries, Concord, Calif. [A]
Gravelle, Warren G., associate design engineer, Ringel and Associates, Chico, Calif.
Mangold, Robert A., chemist, Material Test Laboratory, Westinghouse Electric Corp., Sunnyvale, Calif. [A]
Matheu, Robert R., partner, Pregnoff & Matheu, San Francisco, Calif.
Morales, Ray, assistant civil engineer, Department of Water and Power, Los Angeles, Calif. [A]
Nakai, Ray Takac, mechanical design engineer, Link Div., General Precision, Inc., Palo Alto, Calif. [A]

Northwest District

Kersnar, Frank, J., chief engineer, Metropolitan Engineers, Seattle, Wash.
Krivanek, H., chief designer, Engraving Dept., Letson & Burpee, Ltd., Vancouver, B. C., Canada.
Lakewold, Claude E., field test director, Inland Analytical Laboratories, Spokane, Wash.
Post, James W., chief chemist, The Olympic Portland Cement Co., Ltd., Bellingham, Wash.

Ohio Valley District

Fuel Research and Instrument Co., K. E. Kindsay, vice-president, Charleston, W. Va.
Trailmobile, Inc., Jack E. Cook, test engineer, Cincinnati, Ohio.
Cholak, Jacob, associate professor, College of Medicine, University of Cincinnati, Cincinnati, Ohio.
Thompson, Robert S., president, The H. P Deuscher Co., Hamilton, Ohio.

Philadelphia District

Allen, John W., manager of engineering, Nondestructive Testing, Instruments Div., The Budd Co., Phoenixville, Pa.
Apmann, Robert Proctor, instructor in civil engineering, Lehigh University, Bethlehem, Pa. [A]
Bennett, C. Eugene, director of applications, F & M Scientific Corp., NCC Airbase, New Castle, Del.
Brown, Silas M., assistant chief metallurgical engineer, Bethlehem Steel Co., Inc., Bethlehem, Pa.
Crimm, Ralph G., Jr., sales manager, Admixtures, Inc., Upper Darby, Pa.
Ferlanie, William C., materials engineer, Collins & Maxwell, Inc., Easton, Pa.
Mikita, Joseph J., technical manager, Petroleum Chemicals Div., E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.
Reymer, Stephen Edward, salesman, Sales Dept., Bethlehem Steel Co., Inc., Bethlehem, Pa. [A]
Smith, Dudley C., laboratory director, Kimble Glass Co., Subsidiary of Owens-Illinois, Vineland, N. J.
Volk, Donald J., president and general manager, Alloy Steel Casting Co., Southampton, Pa.
Zampino, Peter A., manager, metallurgical services, The Brush Beryllium Co., Shoemakersville, Pa.

Pittsburgh District

Backman, William J., Crucible Steel Company of America, Pittsburgh, Pa.
Blackburn, George T., works engineer, Walworth Co., Greensburg, Pa.
Dickson, John H., assistant refractories engineer, Wheeling Steel Corp., Steubenville Works, South Div., Steubenville, Ohio.
French, John M., manager of development, Corrosion Engineering Products Dept., Pennsalt Chemicals Corp., Natrona, Pa.
Groetzinger, William F., project engineer, The Rust Engineering Co., Pittsburgh, Pa.
Turkanis, Marvin M., project engineer, sources, Nuclear Materials and Equipment Corp., Apollo, Pa. [A]

Rocky Mountain District

Thiokol Chemical Corp., Utah Div., Earl L. Gray, supervisor, Materials and Processes Section, Rocket Design Engineering Dept., Brigham City, Utah.
Batley, Charles H., superintendent, Sactle Concrete Co., Inc., Colorado Springs, Colo.
Casto, Clyde C., manager, Physical and Analytical Chemistry Dept., Rocket Power, Falcon Field, Mesa, Ariz.
Colorado, University of, Department of Civil Engineering, Boulder, Colo.

(*Continued on page 348*)

NEW MEMBERS

(*Continued from page 346*)

Grandy, George A., management trainee, Columbia-Geneva Steel Div., United States Steel Corp., Provo, Utah. [A]
Rice, John, engineer, Merritt-Chapman & Scott Corp., New York, N. Y. [A]
Thannoun, Sabiha, chemist, Public Works Laboratory, City of Albuquerque, Albuquerque, N. Mex. [A]

Southeast District

Allen, John P., engineer of bridges, Southern Railway System, Knoxville, Tenn.
De Castro, Raimundo, chemist, Hollywood, Fla.
Kruse, H. Samuel, partner, Watson & Deutschman, Miami, Fla.
MacNeill, Donald C., project engineer, Reynolds, Smith & Hills, Jacksonville, Fla.
Skillman, Joe H., Skilltain Laboratory, Lakeland, Fla.
Storm, Walter, Construction Specification Inst., Miami Chapter, Miami, Fla.
Vachon, Reginald I., engineer, E. I. du Pont de Nemours and Co., Inc., Orange, Tex. [A]

Southern California District

Baral, Paul, testing and evaluations, Paper Mate Manufacturing Co., Santa Monica, Calif.
Blaszkowski, Bernard A., associate engineer, Convair Astronautics, A Division of General Dynamics Corp., San Diego, Calif. [A]
Ferrin, Frederick J., senior research engineer, Autonetics, A Division of North American Aviation, Inc., Downey, Calif.
Meyer, Ernst, engineer, Autonetics, A Division of North American Aviation, Inc., Downey, Calif.
Parker-Chrapek, Larryn J., production superintendent, American Latex Products Corp., Hawthorne, Calif.
Salter, Harry, chief chemist, W. J. Voit Rubber Corp., Los Angeles, Calif.
Schmitt, H. Paul, resident chemist, Macmillan Petroleum Corp., Long Beach, Calif.
Teal, Edward J., structural engineer, A. C. Martin and Associates, Los Angeles, Calif.

Southwest District

Baker, Donald L., engineering assistant, Texas Highway Dept., Houston, Tex.
Brown, Rene P., manager, Research and Control, Cosden Petroleum Corp., Big Spring, Tex.
Clemens, Robert W., Houston Tex.
Gogol, Michael, mechanical and test engineer, Texas & New Orleans Railroad Co., Houston, Tex.
Hynes, Joe H., chief draftsman, Gray Tool Co., Houston, Tex.
Kelly, Allen E., structures engineer, Convair, A Division of General Dynamics Corp., Fort Worth, Tex. [A]
Martin, Sidney M., chief chemical engineer, Lone Star Boat Co., Plano, Tex.
Rea, Clarence R., director of quality control, Wesco Materials Corp., Dallas, Tex.
Riherd, Carl B., quality control chemist, Cosden Petroleum Corp., Big Spring, Tex.

Washington D. C. District

American Tobacco Co., The, J. S. Osborne, Jr., research chemist, Richmond, Va.
Beattie, John S., director of research, Collins & Aikman Corp., Albemarle, N. C.
Butler, Herbert E., test engineer, Westinghouse Electric Corp., Baltimore, Md. [A]
Evans, Giles L., Jr., executive secretary, Masonry Inst., Inc., Washington, D. C.
Raab, R. H., sales manager, Acoustical Div., Eastern Products Corp., Baltimore, Md.
Sparrow, Edward, chemist, Naval Supply Center, U. S. Naval Station, Norfolk, Va.

Western New York-Ontario District

Aiken, Donald B., senior development engineer, The Carborundum Co., Niagara Falls, N. Y.
Edamura, Henry N., junior engineer, Marshall, Macklin, Monaghan, Ltd., Don Mills, Ont., Canada. [A]
Elder, Lorne C., chief engineer, Wallace Barnes Co., Ltd., Hamilton, Ont., Canada.
Flaherty, Myles P., civil engineer, American Bridge Div., United States Steel Corp., Elmira, N. Y. [A]
Gietzen, Eugene A., chief metallurgist, Bethlehem Steel Co., Inc., Lackawanna N. Y.
Kennedy, T. J., general manager, Niagara Falls Smelting and Refining Div., Continental Copper and Steel Industries, Inc., Buffalo, N. Y.
Mattke, Juergen, process engineer, Delco Appliance Div., General Motors Corp., Rochester, N. Y.
Thomson, Andrew R. D., quality control supervisor, Renfrew Electric Co., Ltd., IRC Div., Toronto, Ont., Canada.
Toronto, The Municipality of Metropolitan, Department of Works, Toronto, Ont., Canada.
Wass, Ernest A., office manager, Valliere Drapery Studio, Rochester, N. Y. [A]

Outside Established Districts

Briggs, Larry L., civil engineer, Henningson, Durham & Richardson, Inc., Omaha, Nebr. [A]
Lennox, James M., operations manager, Mobil Oil Caribe, Inc., Hato Rey, Puerto Rico.

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Antoniou, D. N., president, Shipping and General Agency Co., Ltd., Piraeus, Greece.
Bickford, C. E. K., general manager, Compania Guatemalteca de Maquinaria, Guatemala City, Guatemala.
Bombaci, Nunzio, Engineering Dept., IBM Italia, Milan, Italy.
Carbonell, Celso A., president, Sika Panama, S.A., Panama City, Panama.
Casas Orjuela, Daniel, professor of structural engineering, Facultad de Ingenieria, Popayan, Columbia.
College of Advanced Technology, The Library, E. H. C. Driver, librarian, Birmingham, England.
Cormack, W. J., plant metallurgist, Caterpillar Tractor Co., Ltd., Glasgow, Scotland.
Davies, John Robinson, director, Soiltest International, S.A., Lausanne, Switzerland.
Goldfinger, Paul, professor of chemistry and physics, Universite Libre de Bruxelles, Brussels, Belgium.
Harasyn, Harry, resident engineer, Department of Public Works, Highway Branch, Dauphin, Man., Canada. [A]
Henault, Gilles G., project engineer, The Warnock Hersey Co., Ltd., Montreal, P. Q., Canada. [A]
Hiltner, Alceu Roberto, Sinay Neves and Cia., Ltda., Salvador, Bahia, Brazil.
Kirby, H. W., director of research, The Brown-Firth Research Laboratories, Sheffield, England.
Lavoie, Jean Louis, soils technologist, Quebec Highway Laboratory, Roads Dept., Provincial Government, Quebec, P. Q., Canada.
Lontok, Isabel R., general manager, G. B. Lontok and Co., Escola, Manila, Philippines.
Mori, H., director and engineer, The Daiichi Jitsugyo Co., Ltd., Tokyo, Japan.
Mufti, Fazilat A., chemist, Hydari Industries, Ltd., Hyderabad, West Pakistan. [A]
Nagvajara, Wattana, sales engineer, International Engineering Co., Ltd., Bangkok, Thailand.
Prakash, Ved, general manager, Hargolal and Sons, The Science Apparatus Workshop, Ambala Cantt, India.
Salti, Emile F., senior partner, Associated Industrial Chemical Agricultural Experts, Beirut, Lebanon.
Schieffer, William F., manager, Grancoa, Ltda., Bogota, Colombia.
Schiller, Ewald G., manager, Schiller and Co., Quito, Ecuador.
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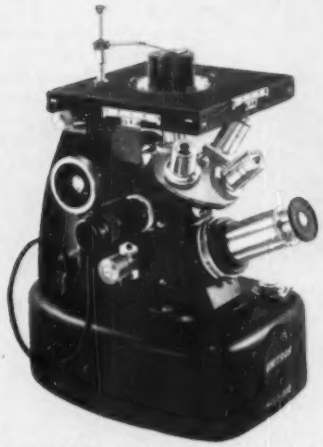

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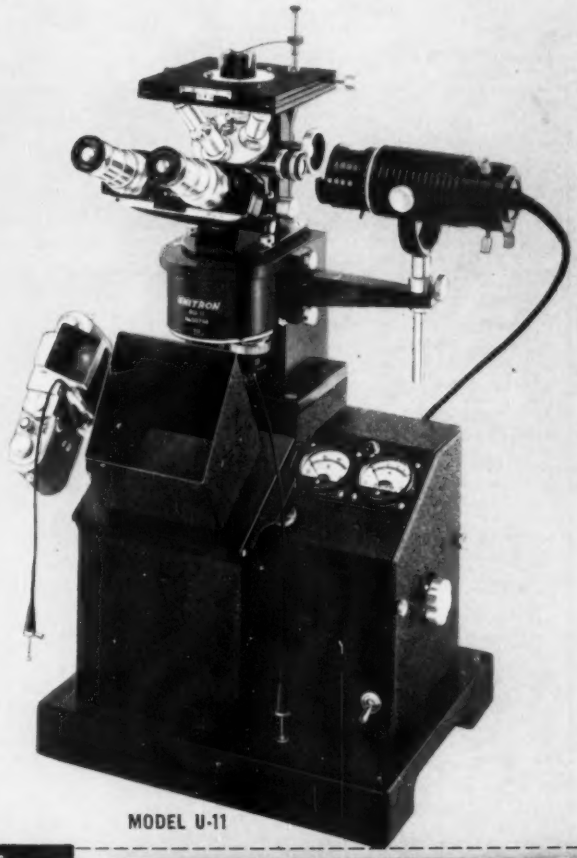

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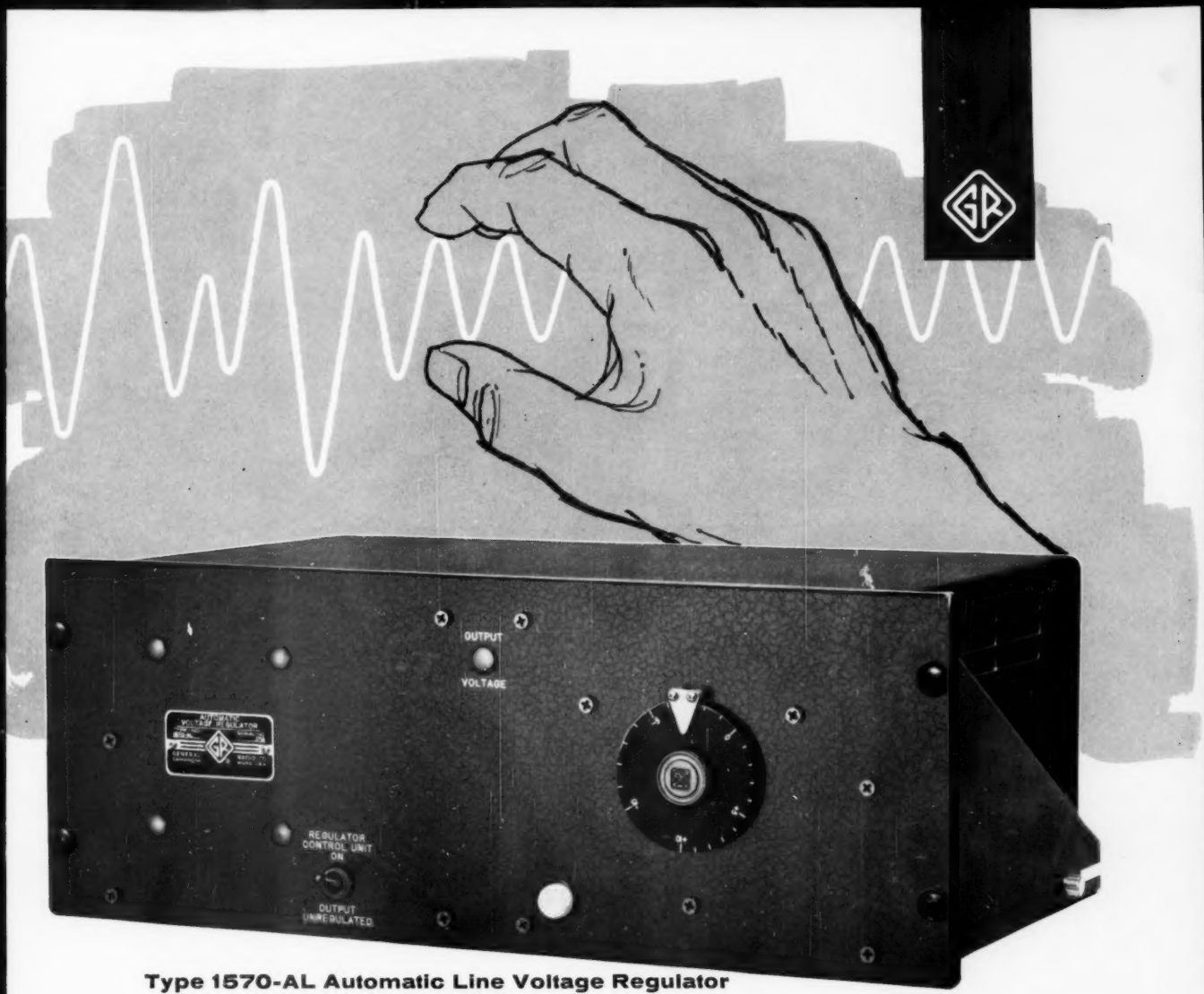

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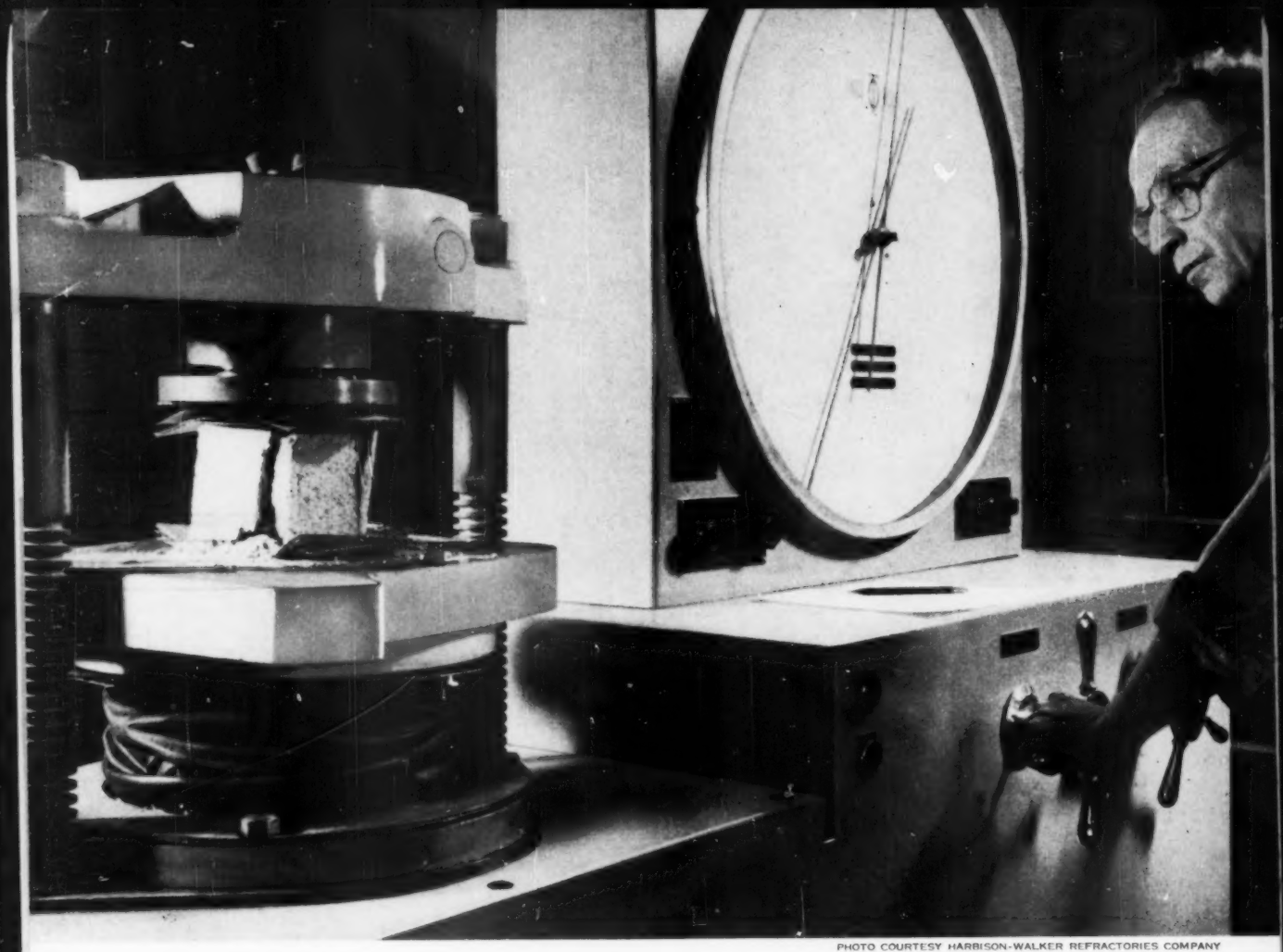

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